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Ecological Changes on Pine-Grassland Burned in Spring, Late Spring, and Winter

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ECOLOGICAL CHANGES ON PINE-GRASSLAND BURNED IN SPRING, LATE SPRING, AND WINTER

BY

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IN SPRING, LATE SPRING, AND WINTER

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser   Date

Head, Biology-Botany Dept.   Date

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DESCRIPTION OF THE BLACK HILLS

Location and extent

South Dakota, one of the Great Plains States, is located in the geographical center of the North American Continent, midway between the North Pole and the equator (U. S. Dep. of the Interior 1967). The Black Hills Region lies along the western border of the state with the greater portions of the Hills in South Dakota, and smaller portions in Wyoming (Fig. 1). The Hills lie between the 43rd and 45th parallels of north latitude, and between the 103rd and 105th meridians of longitude (Newton and Jenny 1880). They cover approximately 142,838 square kilometers (5,150 square miles), including the Bear Lodge Mountains in Northeastern Wyoming (Orr 1959). The Black Hills occupy an irregularly shaped area, about 193 kilometers (120 miles) in length, from north-northwest to south-southeast, and have a width of 64 to 80 kilometers (40 to 50 miles) (Newton and Jenny 1880).

History

Some of the first white men that came to the Black Hills considered them "a true oasis in a wide and dreary desert" of prairie (Dodge 1876). These men were on military or scientific expeditions or were prospectors or fur traders. One of the first expeditions was that of the Hayden Geological Survey party in 1857-1859 (Newton and Jenny 1880). In 1874, a military expedition under General George A. Custer explored the Black Hills and found gold in a number of locations (Storms 1906). In 1875, Colonel R. I. Dodge led a second military expedition into the Hills.

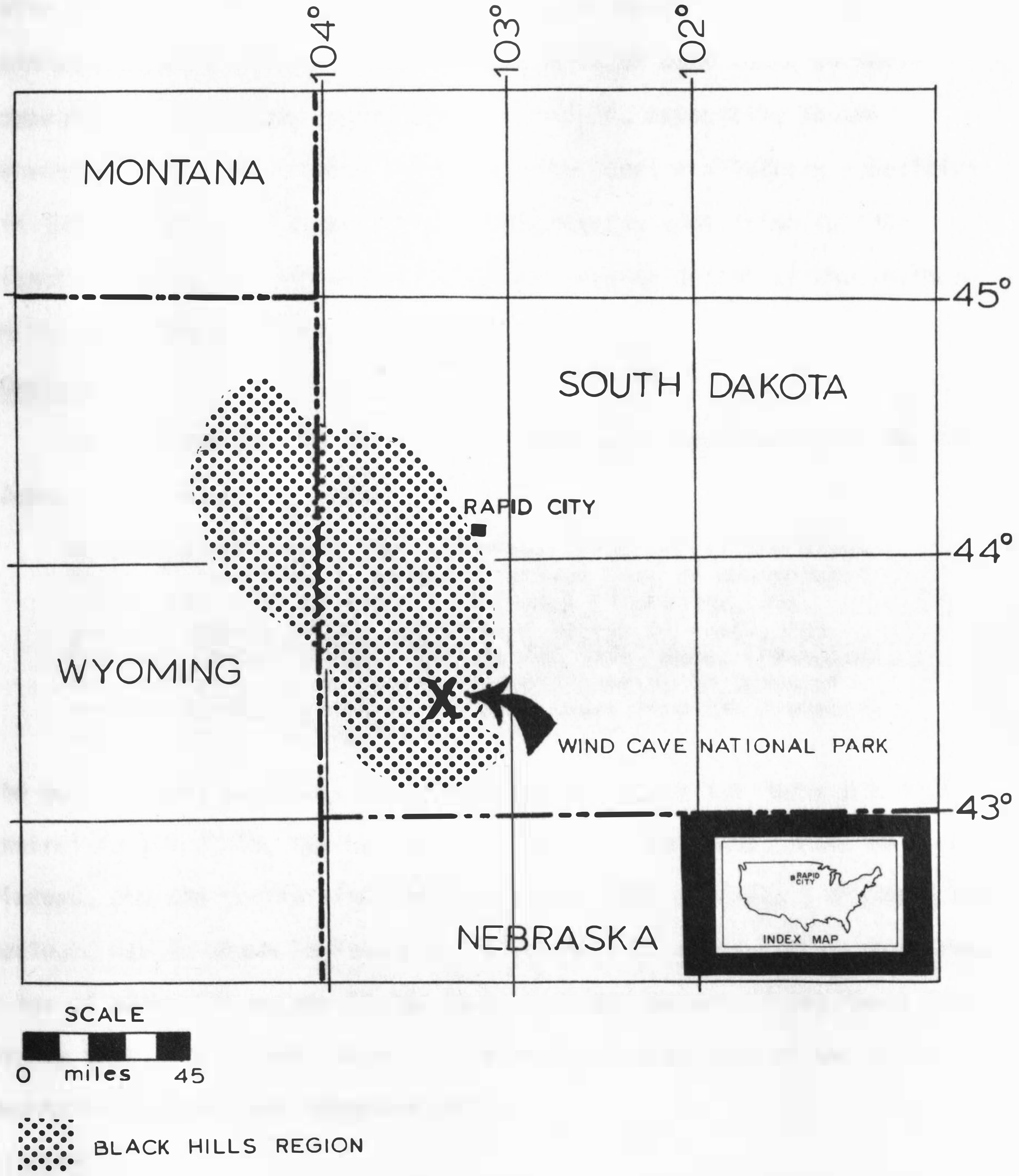


FIGURE 1. Location and Extent of the Black Hills.

With that expedition were W. P. Penny and H. Newton, geologists and mining engineers (Storms 1906). The reports of gold found on those expeditions led to the "gold rush" of 1875-76, especially in the Northern Hills area. Later expeditions included the Rydberg expedition in 1892 (a botanical expedition) and the Darton expedition in 1903 (another geological expedition) provided greater detail of the southern Hills area (Darton 1903).

Geology

Much of the geology of the Black Hills was summed up by Newton and Jenny (1880) when they wrote:

> Generally and simply the geological structure of the Black Hills is as follows: Around a nucleal area of metamorphic slates and schists, containing masses of granite, the various members of the sedimentary series of rocks, the Potsdam, Carboniferous, Trias or Red Beds, Jura, Cretaceous, and Tertiary, lie in rudely concentric belts or zones of varying width, dipping on all sides away from the elevatory axis or region of the Hills.

The most obvious physical features of the Hills are the Hogback Ridges encircling the Hills, the Red Valley within the Hogbacks, the Limestone Plateau, and the Central Area of high ridges (Darton 1903). A simplified geologic map is shown in Figure 2. Elevations of these ridges range from a low of about 975 meters (3,200 feet) to 2,207 meters (7,242 feet) at Harney peak, the highest point in the United States east of the Rocky Mountains (Gartner and Thompson 1973).

Climate

From a botanical standpoint the most important climatological difference between the Hills and the surrounding area is that the Black

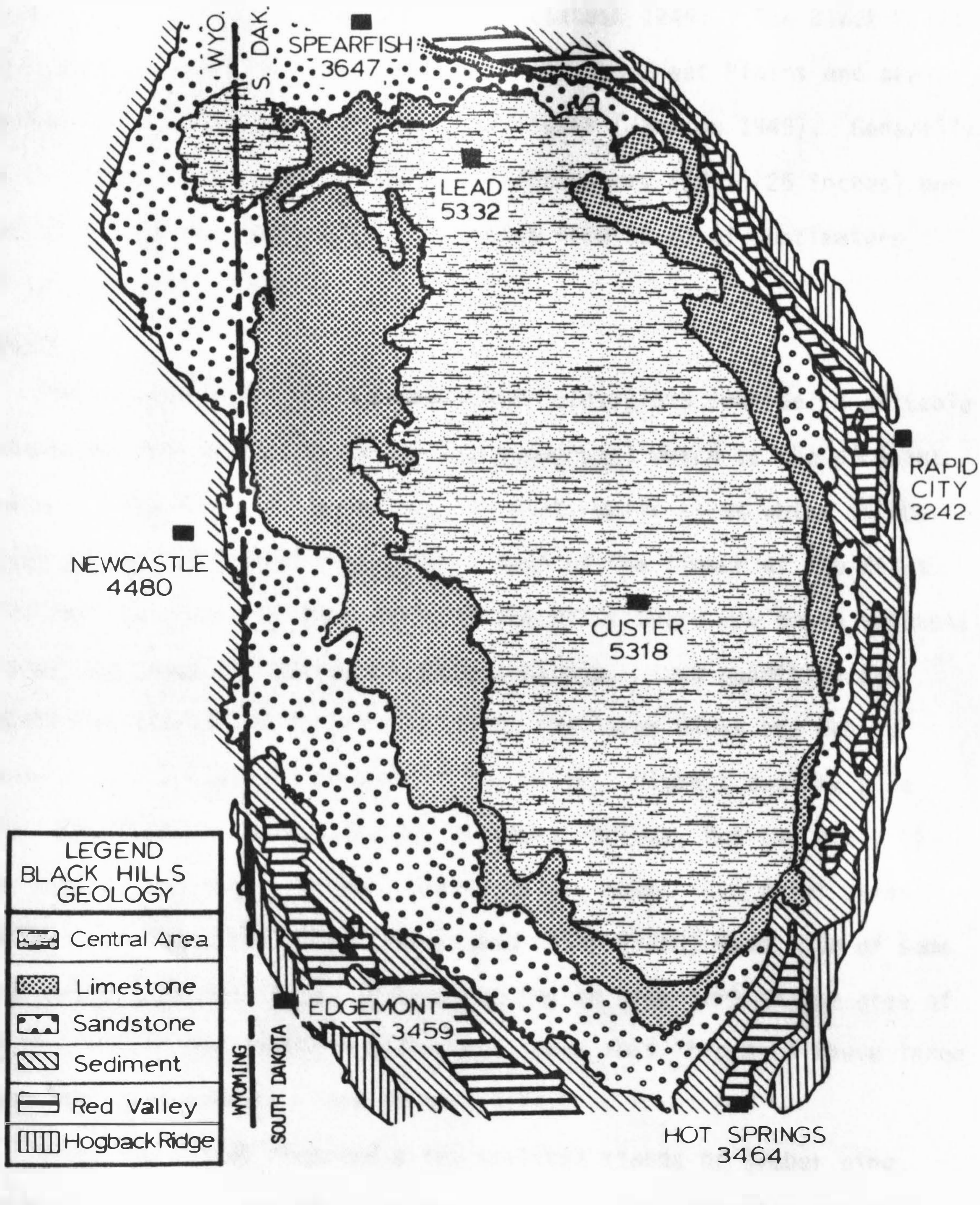


FIGURE 2. Generalized geologic and topographic sketch of the Black Hills.

Hills receive much more precipitation (McIntosh 1949). The Black Hills are situated within the semi-arid region of the Great Plains and precipitation can vary greatly from year to year (Johnson 1949). Generally, the Hills area receives from 46 to 64 centimeters (18 to 25 inches) per year while the surrounding plains receive from 36 to 41 centimeters (14 to 16 inches) annually.

Vegetation

The greater precipitation and higher elevations provides a suitable environment for ponderosa pine (Pinus ponderosa) which is the dominant conifer of the Black Hills region. In cool, moist areas white spruce (Picea glauca) is common (Orr 1959). Much of the timber of the Hills is of poor quality. In many areas of the Hills there are dense thickets of pine and "doghair" stands of young saplings. This condition can probably be attributed to the logging of the large pines and nearly complete fire protection throughout the Hills. Highest quality pine sites are found in the central and northern regions, but the trees become smaller and more profusely limbed as one moves into drier areas (Gartner and Thompson 1973). Newton and Jenny (1880) made note of some large pines (100 feet tall, 35 to 40 inches in diameter) in the area of French Creek in the southern Hills, but added that "trees of these large dimensions are, however, rare in the Hills."

Thelinius (1970) reported a few isolated stands of limber pine (Pinus flexilis) in the Black Hills. Quaking aspen (Populus tremuloides) and paper birch (Betula papyrifera) are common on cool, shaded sites, especially in the northern Hills. Bur oak (Quercus macrocarpa) is also common, but is usually small and scrub-like in form.

Occurring along streams, within and extending from the Black Hills, are willows (Salix spp.), redosier dogwood (Cornus stolonifera), and water birch (Betula occidentalis). Other deciduous trees found in the Hills include elm (Ulmus spp.), wild plum (Prunus americana), pin cherry (Prunus pennsylvanica), boxelders (Acer negundo), cottonwoods (Populus spp.), and mountain ash (Sorbus scopulina) (Gartner and Thompson 1973).

McIntosh (1949) noted that "the mixed paririe association dominates much of the plains region surrounding the Black Hills, extends into the larger park-like areas of the Hills proper." True prairie grasses found in this climax include prairie junegrass (Koeleria cristata), needle-grasses (Stipa comata, S. spartea, S. viridula), and wheatgrasses (Agropyron smithii and A. trachycaulum). Shortgrasses found in this climax include buffalograss (Buchloe dactyloides) and the grama grasses (Bouteloua curtipendula, B. gracilis, and B. hirsuta).

McIntosh (1949) labelled areas of shallow soil that supports a bluestem community as the "bunch-grass subclimax." He wrote:

> On the rocky ridges extending from the Hills into the Red Valley encircling the Hills and upon the adjacent uplands the bunch-grass association forms a zone intermediate be-tween the mixed prairie pine forest...
>
> ...The yellow pines (P. ponderosa) are invading this grassland and probably represent the climax vegetation of the area, but here and there are openings acres in extent covered by tall grasses.

The dominant bunch-grass of this subclimax is little bluestem (Andro-pogon scoparius). Big bluestem (A. gerardi), Indiangrass (Sorghstrum nutans), prairie dropseed (Sporobolus heterolepis), stoneyhills muhly

(Muhlenbergia cuspidata), and the previously mentioned shortgrasses are also found in this subclimax. Sedge (Carex spp.) and bluegrasses (Poa spp.) are cool season plants that are commonly found in this subclimax association.

DESCRIPTION OF WIND CAVE NATIONAL PARK

Wind Cave National Park was established in 1903. The cave was privately owned by the McDonald family, who were homesteading the land, until it became a National Park.

The Park is a 11,355 hectare (28,059 acre) tract of mixed grass prairie and ponderosa pine forest lying in the southeastern foothills of the Black Hills (U. S. Dep. of the Interior 1973). The approximate location of Wind Cave National Park is shown in Figure 1. The Park consists of approximately 72 percent rangeland and 18 percent woodland (Baumberger 1977). Elevations range from 1,097 to 1,524 meters (3,600 to 5,000 feet). The average annual precipitation is about 46 centimeters (18 inches), 70 percent falling between May 1 and September 30. Snow cover is usually light and intermittent and the frost-free period averages about 120 days (U. S. Dep. of the Interior 1973).

Ten years after the Park was established, it was stocked with bison (Bison bison), elk (Cervus canadensis), and pronghorn antelope (Antilocapra americana). These animals were native to the area, but had been removed by early settlers. Mule deer (Odocoileus hemionus), whitetail deer (O. virginianus), and blacktail prairie dogs (Cynomys ludovicianus) are also present, as are many other species of small mammals, birds, and reptiles (U. S. Dep. of the Interior 1973).

HISTORY OF FIRE IN THE BLACK HILLS

Early writings recorded the importance of wildfires in the Hills. Dodge (1876) remarked about the damage done by lightning caused fires when he wrote:

> Throughout the Hills the number of trees which bear the marks of the thunderbolt is very remarkable, and the strongest proof of the violence and frequent recurrence of these storms.... The woods are frequently set on fire and vast damage done. There are many broad belts of country covered with tall straight trunks of what was only a short time before a splendid forest of trees....

Newton and Jenny (1880) also emphasized the effect of fire on the forest:

> The Black Hills have been subjected in the past to extensive forest fires, which have destroyed the timber over considerable area. Around Custer Peak and along the limestone divide, in the central portions of the Hills, on the headwaters of the Box Elder and Rapid Creeks, scarcely a living tree is to be seen for miles.... Some portions of the parks and valleys, now destitute of trees, show by the presence of charred and decaying stumps that they were once covered by forests, but generally the pine springs up again as soon as it is burnt off, though sometimes it is succeeded for a time by thickets of small aspens.

Roach (1974) reported that evidence indicates that natural fire occurred on an average of every 6 to 25 years on each acre in the Black Hills.

While Plains Indians apparently burned the grasslands for various reasons, it appears doubtful that they burned areas within the Black Hills region (Gartner and Thompson 1973). The Black Hills were the "abode of the spirits" and the Indians rarely entered the Hills (Dodge 1876). One of the reasons for not entering the Hills given by an Indian interviewed by Dodge (1876) was "that it thunders and lightnings with terrible force, tearing trees to pieces and setting fire to the woods."

When white man settled in the Hills, they tried to suppress the wildfires as best they could. McIntosh (1927) wrote of the emphasis placed on fire control in the early 1900's:

> Within the last 50 years man, fire, and the Black Hills beetle have been the most potent agents in altering the Black Hills flora.... Fire has always been one of the forest's worst enemies. Although the United States Forest Service maintains lookouts in the Black Hills forests during the summer and carries on an active educational program against forest fires, fires are still all too frequent.

A fire suppression policy has been practiced in the Hills until recently when some wildfires and controlled burns have been used to reduce flammable fuels in some areas.

HISTORY OF FIRE IN WIND CAVE NATIONAL PARK

Fires were suppressed in the area even before the Park was established. Fire suppression, combined with the light to moderate grazing by wildlife, has resulted in the accumulations of large amounts of fuel; unnatural thickening and spreading of ponderosa pine; invasion of exotic plants such as Kentucky bluegrass (*Poa pratensis*), Japanese brome (*Bromus japonicus*) and sweetclover (*Melilotus* spp); and prevention of establishment of a natural, complex mosaic of different-aged forests and grasslands (U. S. Dep. of the Interior 1973). Combinations of heavy, unnatural accumulations of fuel, dry weather conditions, and strong winds provided conditions for wild fires which could not be suppressed. Lovaas (1976) reported that "at least 79 lightning fires and 33 man-caused fires were suppressed in and near the Park from 1930 through 1974." In 1964, the "Headquarters Fire" consumed about 5,261 hectares (13,000 acres), damaging both Park Service and bordering private land (Shilts 1976).

In 1968 the Nationwide National Park Service Fire Policy was revised to allow selective wildfire suppression, recognizing that fire could be beneficial. Wildfires in Wind Cave National Park which will not further the area's management objectives are still suppressed.

Experimental prescribed burning was initiated in the Park in the fall of 1973. Strips approximately 38 meters (125 feet) wide were burned along 8 kilometers (five miles) of dirt road through open grasslands in the eastern portion of the Park (Shilts 1976). Three areas were selected along the road and replicated study plots 15.25 x 30.50 meter (50 x 100 foot) were established for the following treatments: pre-frost burn, post-frost burn, early spring burn and control (no burn). These burns were completed in September 1973, February 1974, and April 1974.

Additional burns in the Park have included about 100 hectares (250 acres) of grassland in February of 1974, a dense pine thicket in April of 1974, a 32 hectare (78 acre) timbered ridge in October of 1974, and about 69 hectares (170 acres) of grass and ponderosa pine encroachment in May of 1975 (Shilts 1976).

The research with which this thesis is concerned will, hopefully, provide additional data to develop a prescribed fire management program with the following objectives: reduce wildfire conflagration hazards which exist because of unnatural fuel accumulation, eliminate or reduce exotic plants, invigorate stagnating prairies through reduction of litter, open up dense pine thickets, reduce forest insect problems, create firebreaks, develop a natural vegetative mosaic by preventing unnatural pine encroachment into prairies, and re-establishing pine savannahs (Shilts 1976).

LITERATURE REVIEW OF FIRE ECOLOGY AND PRESCRIBED BURNING

Fires have always played an important role in determining the structure and composition of the ponderosa pine-grassland (Biswell 1973). Biswell (1967) wrote of the primitive forest and fire:

> In primitive forests, fires were a natural feature of the environment. Not only were recurrent fires essential for the forest, but the evolutionary development of the forests and the trees themselves were related to fire.

Such fires were "described as light and creeping surface fires,..." (Biswell 1973).

Forest fires have acted as a thinning agent creating open parks and establishing natural mosaics of uneven-aged stands, comprised of even-aged groups of trees of various age classes (Biswell 1967, 1973; Kayll 1974; Weaver 1967, 1974). Forest fires also reduce the amount of litter or fuel. Periodic removal of fuel maintains the hazard of wildfires at a low level (Biswell 1967, 1973; Weaver 1967, 1974). Period burns improve forage by reducing heavy needle and debris mats that inhibit grass and other desirable plants. Periodic burns also release nitrogen that encourages the growth of these desirable plants, especially nitrogen fixing plants such as lupines (Weaver 1967, 1974).

Grassland climates facilitate fires by the occurrence of dormant periods, dry seasons, and periodic droughts (Vogl 1974). Grassland plants are surface deciduous hemicryptophytes, with the aboveground portions dying back at least once a year (Vogl 1974). In areas of warm season grasses like the Black Hills, grasses will carry fire when dormant in winter and spring (Biswell 1973). Grassland fuels do not always decompose quickly. Therefore, grassland plant debris often accumulates a thick mulch layer. Grasslands have become dependent on fire as a primary decomposition agent and nutrient recycler (Vogl 1974). Recurrent grassland fires have also suppressed the invasion of woody species (Daubenmire 1968, Sauer 1950).

Fires have had an effect on determining the species composition of forest or grassland in that plants that are fire-adapted are selected for by the occurrence of periodic fires. In grassland ecosystems, woody species that do not sprout from their roots can be either eliminated or reduced to a thin stand by repeated burning (Daubenmire 1968). In this way grasses remain dominant, especially those that tiller underground.

Fires in primitive forests also played an important role in the succession of species (Biswell 1967). Natural selection has favored development of characteristics that make certain tree species more flammable (fire-dependent) and at the same time more fire tolerant (Biswell 1973). Trees most resistant to fire had the best chance of surviving and dominating.

Periodic fires assure continued dominance of ponderosa pine for several reasons. Ponderosa pine forests are highly flammable because of a heavy drop of long, resinous needles (Biswell 1973). Ponderosa pine seedlings are also more fire resistant and are more apt to survive than most of the associated species (Weaver 1974).

Failure to recognize that ecosystems may be fire-adapted has resulted in a great deal of mismanagement (Odum 1971). Fire exclusion and suppression by man has resulted in heavy accumulations of fuels, disease, and dense thickets of poor quality trees (Biswell 1973). In recent years, man has used periodic burning as a means to reduce the danger of wildfires.

There are three types of periodic burning: convenience burning, controlled burning, and prescribed burning. Vallentine (1971) defined each type of burning as follows:

> Convenience burning: considers only the time and place of firing with little or no attempt at control.
>
> Controlled burning: planned application and confinement of fire for a preselected land area.
>
> Prescribed burning: systematically planned firing of land when weather and vegetation favor a particular method of burning that can be expected to maximize benefits.

Periodic burning may be used for a variety of purposes. A comprehensive list of purposes was given by Kayll (1974):

(1) to remove unpalatable growth remaining from previous seasons,
(2) to stimulate growth during seasons when there is little green grazing,
(3) to control or destroy insects and disease,
(4) to control the encroachment or development of undesirable plants and encourage desirable food plants such as legumes for both forage and soil improvement, or shrubs for berry production,
(5) to aid in the better distribution of animals on a range or management unit, including bird habitat,
(6) to remove accumulated fuels occurring naturally or as a consequence of logging or cultivation,
(7) to stimulate seed production or opening of cones and prepare seedbeds for seeding, either naturally or artificially,
(8) to establish fire breaks in a system of protection from wildfire, or
(9) to provide training for fire fighters and fire researchers.

To accomplish a specific management objective, one must have a knowledge of fire behavior. The amount and rate of heat released as vegetation burns depends on weather conditions, topography, and the kind, amount, and disposition of the fuel (Daubenmire 1968). The amount and rate of heat released by a fire under a chosen set of conditions can be controlled by the method used to burn the area: through the use of headfires (with the wind) or backfires (against the wind), burning up-slope or downslope, or a combination of these methods (Kayll 1974, Vogl 1974). The season during which the burning is done will also be determined by the management objective for that burn (Daubenmire 1968, Kayll 1974). Depletion of root stocks, the amount of grazing, and the amount of precipitation during the growing season are factors to be considered for determining the frequency of burning (Daubenmire 1968, Kayll 1974, Vallentine 1971). The best results of prescribed burning are accomplished when all factors are considered for a specific management objective.

DESCRIPTION OF THE STUDY AREAS

Two separate areas were selected for the burning treatments. The Rankin Ridge study area was chosen because of its accessibility from a main highway, and because it was a large, uniform area with pine encroachment. An area in Wind Cave Canyon was burned to create a fire break through heavy fuels. The area included three vegetation types that could be studied: grassland, shrubs, and ponderosa pine.

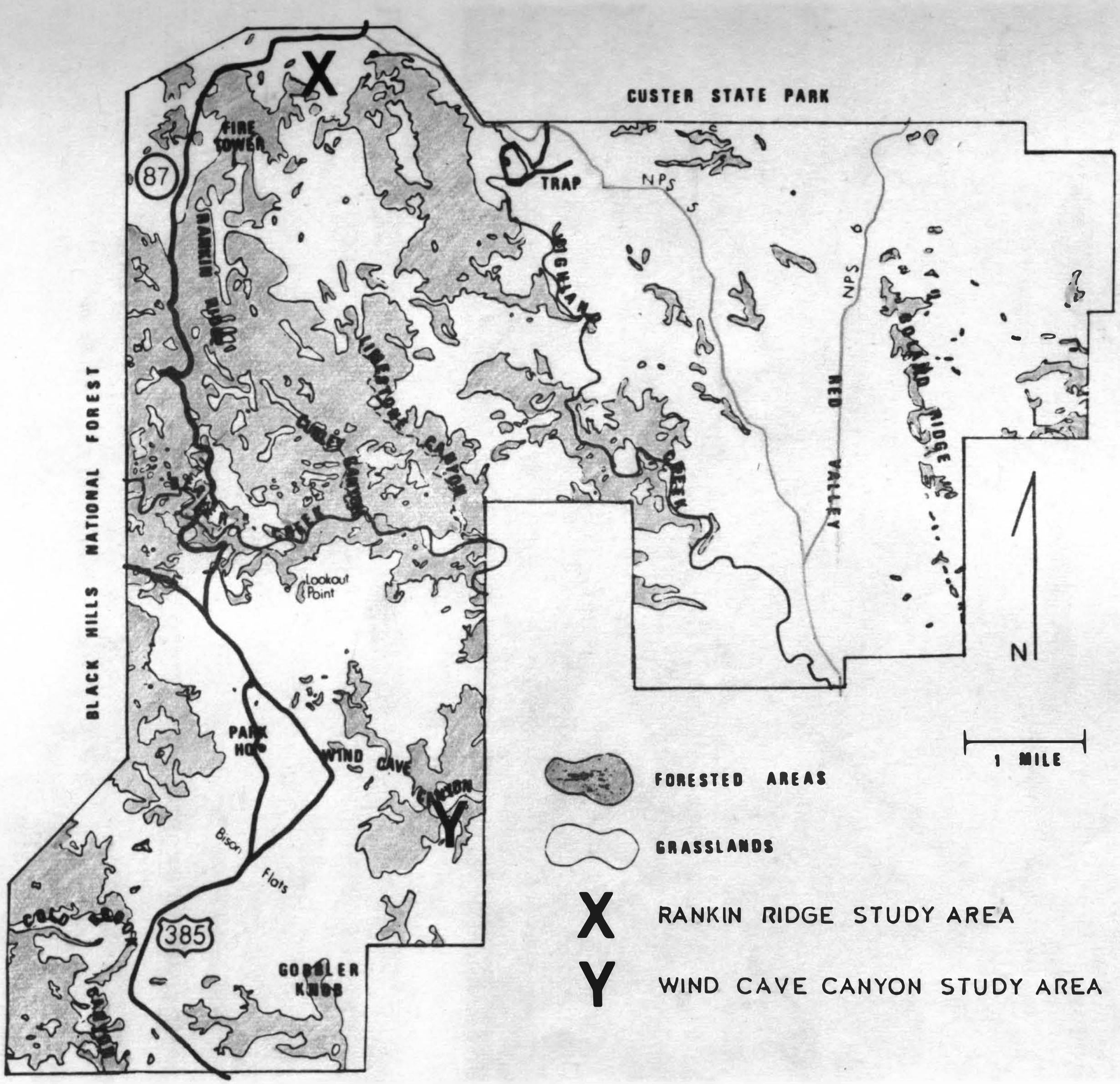
RANKIN RIDGE STUDY AREA

Vegetation

The Rankin Ridge study area was located in the northwest corner of the Park (Fig. 3). The vegetation of the area was that of the bunchgrass subclimax discussed previously. Little bluestem, big bluestem, bluegrasses, grama grasses, and wheatgrasses were the most common grasses of this association. (The scientific epithets for all common names of plants are given in Appendix A.) A few species of sedge were also found in this association. Pine encroachment was evident along the southern border of the study area and extended into the study area.

Physical features

Soils of the Rankin Ridge study area were deep, cobbly loams with a 6 to 15 percent slope (U. S. Dep. of Agri. 1969). A soil map of the study area is shown in Figure 4. The exposure of the study area was in a north-northeast direction. Elevation of the study area ranged between 1,341 and 1,366 meters (4,400 and 4,480 feet), but all sampling was done between 1,353 and 1,366 meters (4,440 and 4,480 feet) (Fig. 5).


CUSTER STATE PARK
BLACK HILLS NATIONAL FOREST
X
Y
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385
FIRE TOWER
RANKIN RIDGE
TRAP
NPS 5
NPS 6
HIGHLAND
LIMESTONE CANYON
CURLEY CANYON
BEAVER CREEK
Lookout Point
RED VALLEY
BOLAND RIDGE
PARK HQ
WIND CAVE CANYON
Bison Flats
COLD BROOK CANYON
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RANKIN RIDGE STUDY AREA
WIND CAVE CANYON STUDY AREA

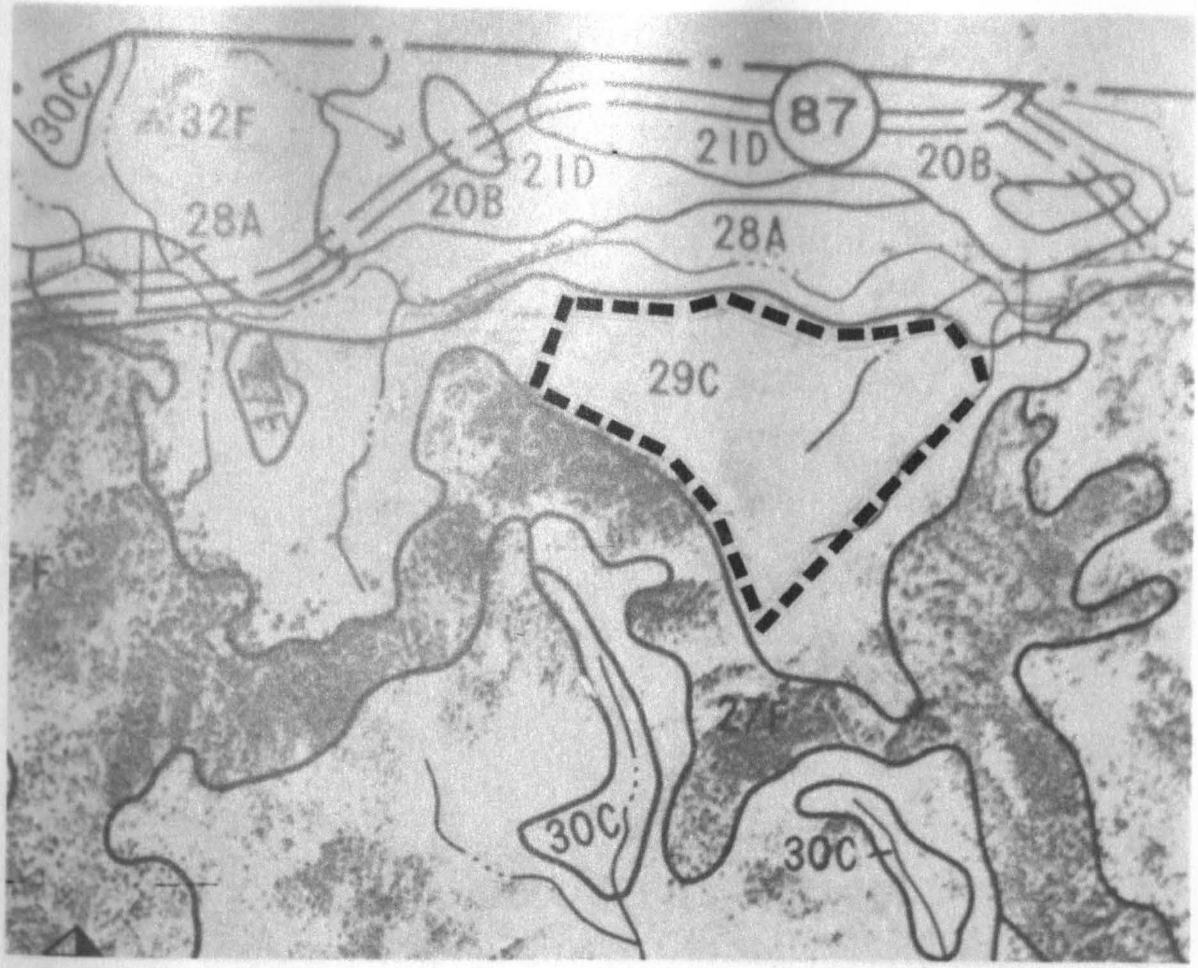


FIGURE 4. Soil Map of the Rankin Ridge Study Area.

Key:

29 C	Deep, cobbly loams, 6 to 15% slope
28 A	Deep, black colored, loamy alluvial soils, 0 to 2% slope
27 F	Deep, stony loams over schists and granite developed under woodlands, 15 to 40% slope
■ ■ ■	Outline of study area

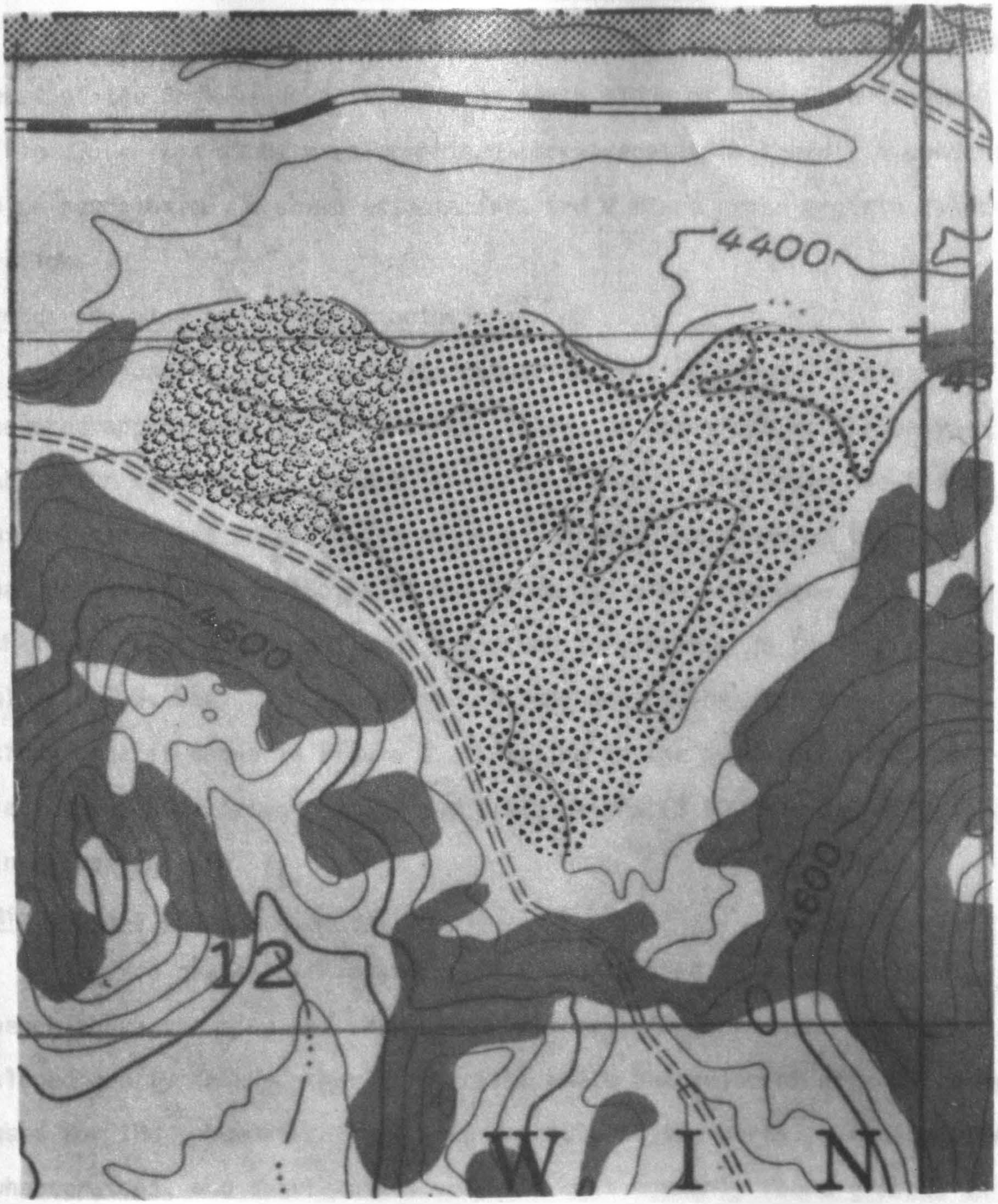
FIGURE 5.

Topographical Map of the Rankin Ridge Study Area.

Key: Control

Spring Burn

Winter Burn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WIND CAVE CANYON STUDY AREA

The Wind Cave Canyon study area was located approximately two miles east of the Park headquarters on the south slope of Wind Cave Canyon (Fig. 3). This study area comprised three vegetation types: a ponderosa pine association, a shrub association, and a mixed grass prairie association.

Ponderosa pine and shrub associations

The ponderosa pine association was an area of "doghair" pine that covered approximately the lower two-thirds of the slope of the canyon above the secondary terrace on the canyon floor. The upper one-third of the slope was occupied primarily by shrubs. Exposure of the slope was north-northwest. Soils of the ponderosa pine area were deep and shallow, reddish colored loams over sandstone with a 25 to 40 percent slope (U. S. Dep. of Agri. 1969). A soil map of the Wind Cave Canyon study area is shown in Figure 6. Sampling in the ponderosa pine association was done between 1,189 and 1,213 meters (3,900 and 3,980 feet) in elevation (Fig. 7).

Mixed grass prairie association

A mixed grass prairie association was located on a nearly level bench above the pine and shrub associations. The area that was burned sloped gently in a southerly direction while the adjacent area which was used for the unburned control sloped gently to the north. Needlegrasses, wheatgrasses, and shortgrasses were the most commonly found grasses in this association. Soils were deep, dark reddish colored silt loams with a 2 to 6 percent slope (Fig. 6). Sampling was done between 1,213 and 1,219 meters (3,980 and 4,000 feet) (Fig. 7).

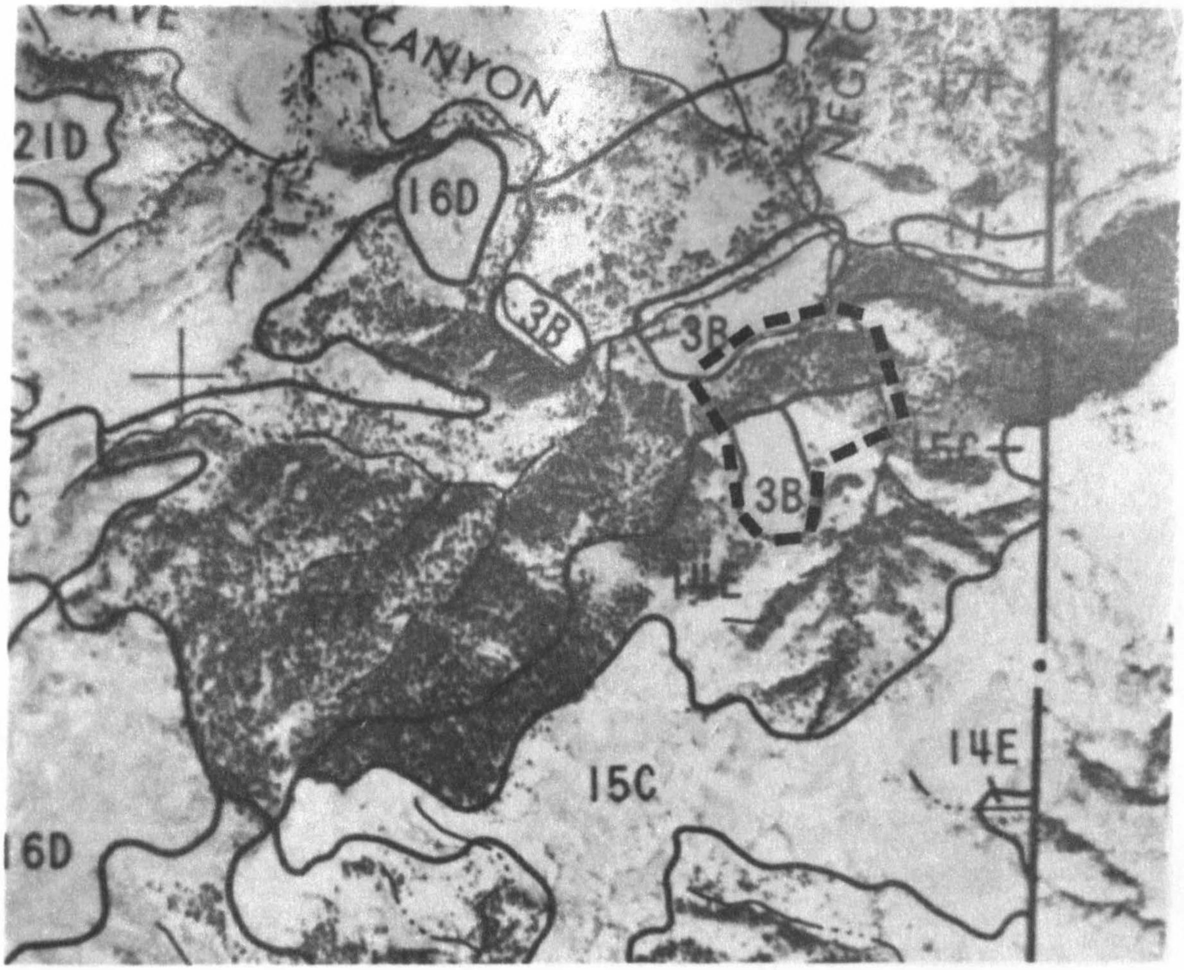


FIGURE 6. Soil Map of the Wind Cave Canyon Study Area

Key: 17 F Deep and shallow, reddish color loams over sandstone, 25 to 40% slope

3 B Deep, dark reddish colored silt loams, 2 to 6% slope

14 E Shallow silt loams over purple limestone, and rock outcrop, 9 to 40 % slope

15 C Shallow and deep silt loams over purple limestone, 9 to 40 % slope

▬ ▬ ▬ Outline of study area

FIGURE 7.
Topographical Map of the
Wind Cave Canyon Study Area.

Key:

Control
Spring Burn


3900

METHODS OF STUDY

TREATMENTS

Burning treatments imposed at both study areas were originally designed to permit evaluation of burning at different seasons of the same year. Because of adverse climatic conditions for prescribed burning during the spring of 1976, treatments were limited to the following:

Wind Cave Study Area:
(1) Spring burn (April 21, 1976)
(2) Unburned control

Rankin Ridge Study Area:
(1) Late spring burn (May 27, 1976)
(2) Winter burn (March 1, 1977)
(3) Unburned control.

BURNING TECHNIQUES

Wind Cave Canyon study area

Approximately 14 hectares (35 acres) were burned in Wind Cave Canyon. Fire lines were built using a Bean high pressure pump with two nozzles laying down two strips of fire retardant, Fire-trol 936,[1/] 2 to 3 meters (6 to 9 feet) apart. Vegetation between the two strips was then burned. Nearly all fire lines were constructed from the back of a moving pumper unit. The east side was bordered by an old fire trail which was burned clear. The west side was not accessable with a moving vehicle, and the line was built by men with portable pumps. All lines were completed prior to the burning day.

[1/] Mention of manufacturer trade names does not constitute endorsement by South Dakota State University.

Firing at the Wind Cave Canyon study area was initiated on the bench above the ponderosa pine. At the time of firing, the wind was out of the southeast. (Fire weather data for all burns is given in Table 1.) The south fire line was reinforced by burning west to east strips from the existing line working toward the slope. The fire was then backed slowly downhill through the mountain mahogany to reduce fuels and minimize damage to the shrubs. Firing was continued along the east edge and allowed to burn with the wind through the ponderosa pine and across the secondary terrace below the pine. Burning was initiated at approximately 8:30 A.M. and was completed by 11:30 A.M.

Rankin Ridge study area

Fire lines for the spring burn at the Rankin Ridge study area were built along the northwest, northeast, and southeast edges. (Figure 5 shows the location of the spring burn). These lines were built like those at the Wind Cave Canyon study area from a moving vehicle. The southwest edge was a fire trail which was burned clear.

Firing was initiated on the northwest and southwest edges. These lines were widened by burning into the wind. After these lines were wide enough to provide a fire break, the northeast and southeast edges were ignited. A headfire carried the fire across the study area. Approximately 12 hectares (30 acres) were burned.

Fire lines for the winter burn at the Rankin Ridge study area were built on the northeast and southeast edges following the same procedures used for previous burns. (Figure 5 shows the location of the winter burn). The fire trail on the southwest edge was burned clear. On the

Table 1

Fire Weather Data

Date of Burn	Time	Location	Temperature	Relative Humidity	Wind
4-21-76	0600	Wind Cave Canyon	48°F	49%	NNW 4 - 9 mph
4-21-76	0825	Wind Cave Canyon	70°F	40%	NW 7 - 12 mph*
5-27-76	0900	Rankin Ridge	70°F	38%	ENE 4 - 7 mph
3-1-77	1100	Rankin Ridge	30°F	78%	SSE 3 - 6 mph

* At 0845 the wind switched to SE 8 - 12 mph.

day of firing a strip of fire retardant was sprayed on the northwest edge bordering the spring burn.

Firing was initiated at the southwest corner, and the northwest, northeast, and southwest lines were widened by burning into the wind. When these lines were sufficiently wide, the southeast edge was ignited and a headfire carried the fire across the study area. Approximately 18 hectares (45 acres) were burned. Burning was initiated at approximately 10:00 A.M. and was completed by 11:30 A.M.

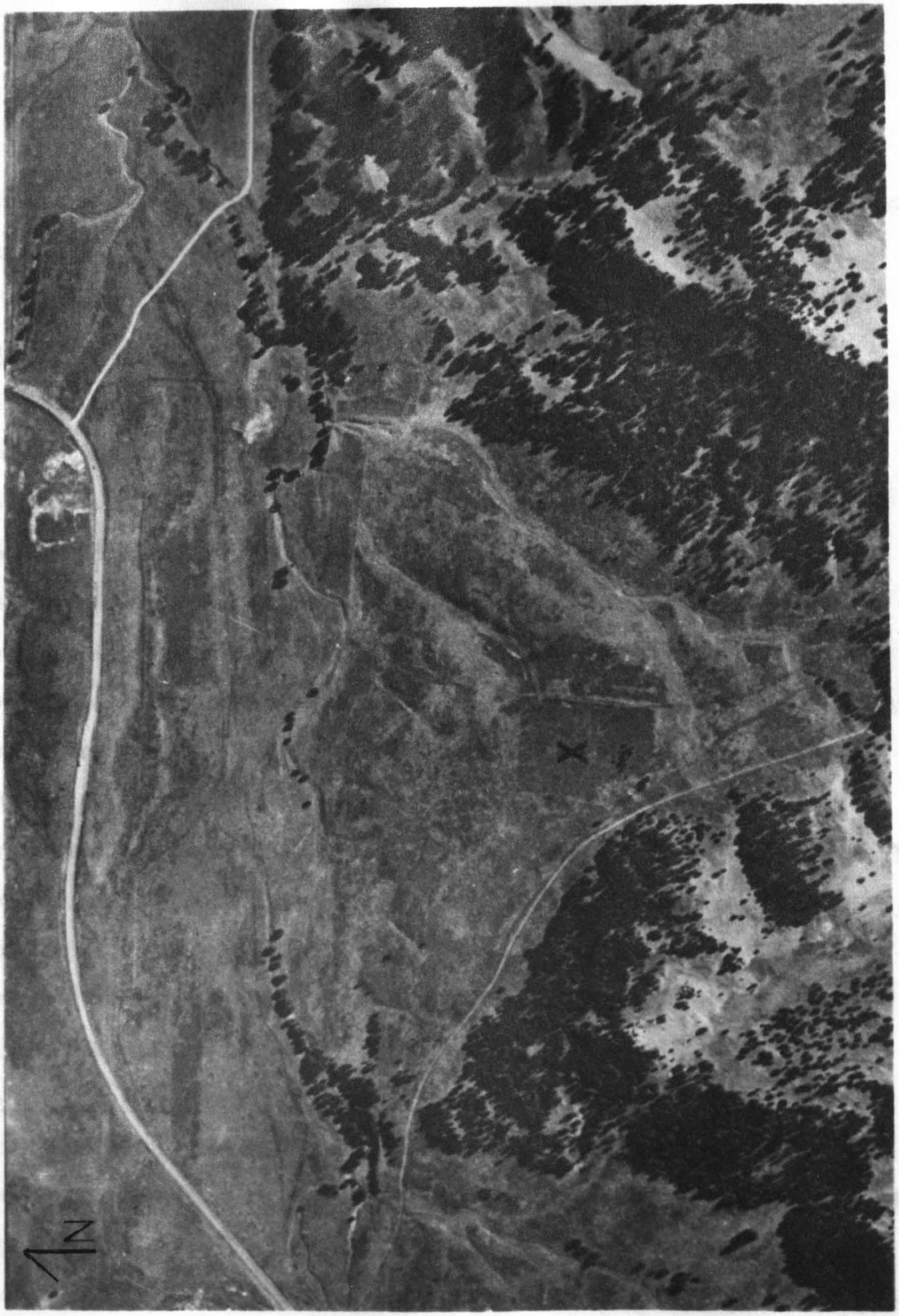
SAMPLING LOCATIONS

Rankin Ridge study area

Sampling at the Rankin Ridge study area was done between 1,353 and 1,366 meters (4,440 and 4,480 feet) in elevation (Fig. 5). Elevational restrictions were imposed in order to insure that sampling was conducted on a uniform soil type. At 1,353 meters (4,440 feet) the slope became steeper and leveled off into a drainage area where alluvial soils existed (Fig. 4). Fairyrings and buffalo wallows were avoided when sampling. An area which had been either mowed or used for pasture in past years was also avoided except for sampling pine encroachment. An aerial photograph taken in 1972 shows the outline of this area (Fig. 8).

Wind Cave Canyon study area

The ponderosa pine association was sampled across the entire slope of the burn. The area of "doghair" pine that bordered the burn on the east edge was used as an unburned control (Fig. 7). A large drainage (draw) within the burn was avoided for sampling purposes.


N
X

Sampling of the mixed grass prairie association was done on both sides of the south fire line using the area south of the line as the unburned control (Fig. 7). The top of the slope of the burned area and buffalo wallows were avoided when sampling.

SAMPLING METHODS: VEGETATION

Fuel load sampling

Standing vegetation and mulch were sampled before burning at the Rankin Ridge study area for determining fuel quantity. Samples were collected on May 20, 1976, before the spring burn, and on November 11 and 12, 1976, before the winter burn. On the spring burn, standing vegetation was clipped to ground level in circular 0.0920 square meter (one square foot) plots and sacked. Mulch, current green vegetation, and dead standing vegetation were separated in the laboratory. Samples were oven-dried at 70^{o}C for 24 hours and weighed. Four rows of five samples per row were clipped in the area to be burned. On the winter burn, standing vegetation was clipped to ground level in 0.3048 x 1.463-meter (1 x 4.8-foot) plots and sacked. Mulch was sacked separately. Samples were oven-dried at 70^{o}C for 24 hours and weighed. Two rows of ten samples per row were clipped on the area that was to be burned and on the unburned control.

1976 vegetation yield sampling

Vegetation yields were sampled in August and September of 1976. The current year's growth was clipped to ground level in 0.6096 x 1.4630-meter (2 x 4.8-foot) plots in each treatment except for the pine association. There, 0.5016 x 0.4064-meter (19.75 x 16-inch) plots were clipped. Portable wire exclosures (cages) were placed on the burn treatments at the start of the growing season. Samples were taken from within the caged areas on the burn treatments.

The cages at the Rankin Ridge study area were placed in four rows of five cages per row across the slope of the hill. Two rows of five samples per row were clipped on the unburned control. The cages at the Wind Cave Canyon study area were placed in three rows of five cages per row across the slope of the hill. Three rows of five samples were clipped on the unburned control. Clipping procedure at the Rankin Ridge study area entailed the separation of vegetation into eight categories: little bluestem, big bluestem, western wheatgrass, bluegrasses, forbs, shrubs, shortgrasses, and other miscellaneous grasses and sedges. Clipping procedure at the Wind Cave Canyon study area entailed the separation of vegetation into nine categories: western wheatgrass, forbs, shrubs, needleandthread, green needlegrass, bluegrasses, shortgrasses, and other miscellaneous grasses and sedges, and little bluestem. Samples were sacked, oven-dried at 70°C for 24 hours, and weighed.

1977 vegetation yield sampling

Vegetation yields were sampled in July and August of 1977. The current year's growth was clipped to ground level in 0.3048 x 1.4630-meter (1 x 4.8-foot) plots except for the pine association which were 0.5016 x 0.4064-meter (19.75 x 16-inch) plots. Cages were placed on all treatments except for the pine association. Samples were taken from within the caged areas. On each treatment the cages were arranged in three rows of five cages per row across the slope of the hill. Clipping procedure at the Rankin Ridge study area entailed the separation of vegetation into 10 categories: little bluestem, big bluestem, western wheatgrass, needlegrasses, bluegrasses, shortgrasses, forbs, shrubs, and other miscellaneous grasses and sedges. Clipping procedure at the Wind Cave Canyon study area entailed the separation of vegetation into the same categories used in 1976. Samples were sacked, oven-dried at 70°C for 24 hours, and weighed.

In 1976 and 1977, samples taken from the pine association burn treatment were clipped in two rows of ten samples per row across the slope of the hill. Two rows of five samples per row were clipped on the control. Clipping procedure entailed the separation of vegetation into nine categories: little bluestem, big bluestem, wheatgrasses, needlegrasses, bluegrasses, forbs, shrubs, shortgrasses, and other miscellaneous grasses and sedges. Samples were sacked, oven-dried at 70°C for 24 hours, and weighed.

Vegetation density sampling

Plant density was measured on all treatments at the Rankin Ridge study area using a modified angle-order method of estimating a total plant density (Strickler and Stearns 1962). Little bluestem, big bluestem, bluegrasses, sedges, and forbs were selected for density measurements. The percentage composition of each species was multiplied by the total density to obtain a density for each species. Measurements were taken on the spring burn in July 1976, on the control in October 1976, and on the winter burn in August 1977. Two 122 meter (400 foot) transects were staked on each treatment across the slope of the hill. Measurements were taken every 1.22 meters (4 feet) on the spring burn and control, and every 2.44 meters (8 feet) on the winter burn.

Western wheatgrass plant height and density were measured on all treatments except for the pine association. Plant height was measured on June 20, 1977. Measurements were taken to the closest centimeter for 100 ungrazed plants per treatment. Density measurements were taken on July 14 and 18, 1977, using a 0.3048 x 0.3048-meter (1 x 1-foot) frame randomly placed along transects located by restricted randomization. Stem counts were made in 50 frames per treatment at the Wind Cave Canyon study area, and 100 frames per treatment at the Rankin Ridge study area.

Tree density, height, and mortality was measured on the ponderosa pine association at the Wind Cave Canyon study area in 1976 and on the pine encroachment at the Rankin Ridge study area in 1977. The burned area at the Wind Cave Canyon study area was divided into three sections and an unburned control. Four 61 meter (200 foot) transects approximately 6 meters (20 feet) apart were staked in an east-west direction across the slope of the hill in each section. Measurements were made every 6 meters (20 feet) using the angle-order method of estimating density (Strickler and Stearns 1962). On the burned area, measurements were made using living and dead trees. The height of the tree in each quadrant was measured to the closest 2.54 centimeter (inch). The tree was also tagged if it had green and/or brown needles. Tagged trees were re-examined on June 7, 1977, and recorded as dead or alive.

Density of the pine encroachment at the Rankin Ridge study area using the angle-order method of estimating density (Strickler and Stearns

1962). Four 61 meter (200 foot) transects were staked across the slope of the hill. Measurements were taken every 12 meters (40 feet). Again the height of the tree and whether it was dead or alive was recorded.

Plant collection

A collection of some of the plants of the study areas was compiled. Plants were identified, pressed, and mounted. Identification was verified by Professor Charles Taylor, taxonomist at South Dakota State University.

SAMPLING METHODS: SOILS

Soil samples were collected for determining soil moisture, pH, ammonium and nitrate content (Microkjeldahl test), percent total nitrogen (Macrokjeldahl test), percent organic matter (Walkey-Black procedure), and available phosphorus (NaCl and HCl-NH_4F procedures). Standard procedures were used for laboratory analysis (Jackson 1958, Olsen and Dean 1965). Paired samples were collected at depths of 0-1 cm and 1-3 cm at three locations across each treatment at both study areas. Each sample was placed in a container, sealed, and kept cool until laboratory analysis began.

On April 19 and 20, 1976, pre-burn samples were taken on areas that were to be burned that spring at both study areas. Post-burn samples were taken on April 22, 1976, at the Wind Cave Canyon study area. On May 28, 1976, post-burn samples were taken at the Rankin Ridge study area. Soils were sampled on March 1, 1977, prior to the winter burn and immediately after the burn had cooled. Soil samples were also taken from the unburned control at that time. All treatments were resampled on August 24, 1977.

SAMPLING METHODS: ANIMAL USE

Grazing estimates

Grazing estimates of key species were made in 1976 because exclosure cages were placed only on the burned areas and not on the unburned controls. Little bluestem and big bluestem were selected for sampling at the Rankin Ridge study area, while little bluestem and needleandthread were selected for sampling at the Wind Cave Canyon study area. Blade height of 50 plants of each species was measured to the nearest 0.5 cm on the control, under the cages on the spring burn, and outside the cages on the spring burn.

Pellet counts

Three belt transects were established on each treatment area on both study areas except for the pine association. The transects were 2.5 meters (8 feet) wide and 61 meters (200 feet) long. The approximate locations of the transects are shown in Figures 9 and 10.

On June 16 and 18, 1976, all bison feces and antelope, deer, and elk pellet groups inside each belt transect were tabulated and marked with yellow tree marking paint. Feces were tabulated again on November 6, 1976 (a 142-144 day period). Transects were established on the winter burn and feces were marked on all transects on May 19 and 20, 1977. Feces were tabulated again on September 28, 1977 (a 133-134 day period).

PHOTOGRAPHIC TECHNIQUES

Photopoints were established by placing two rows of five stakes across the slope of the hill on each treatment. A Honeywell Pentax Spotmatic 35mm camera mounted on a 1.25 meter (4 foot) tripod was placed

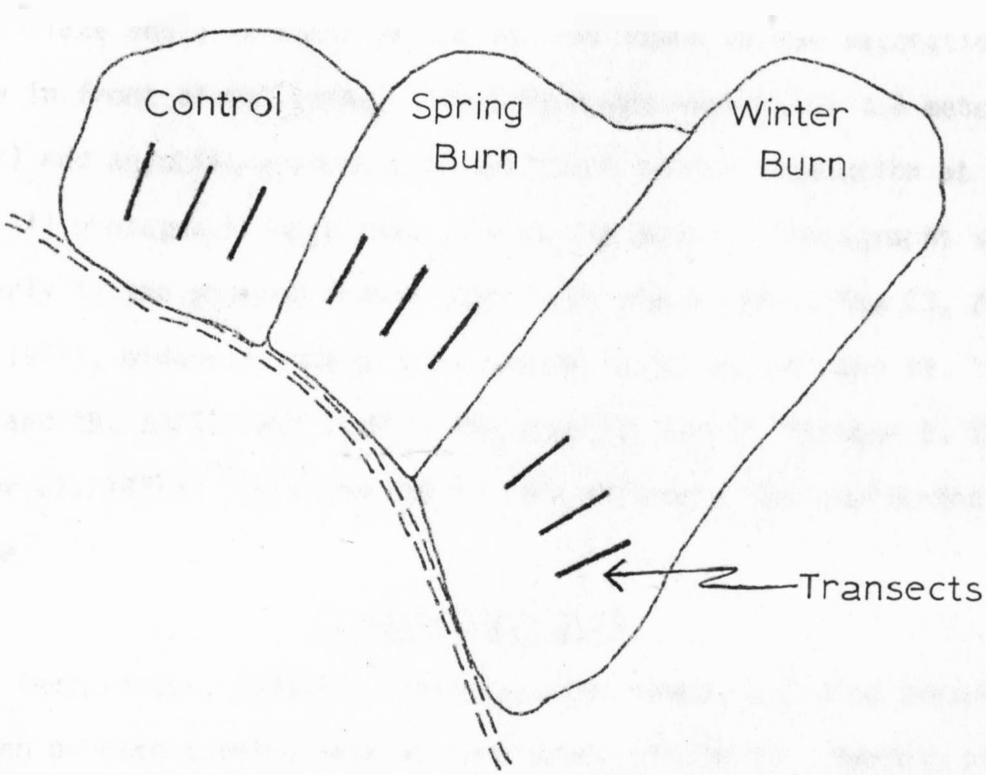


FIGURE 9. Location of Pellet Count Transects at the Rankin Ridge Study Area.

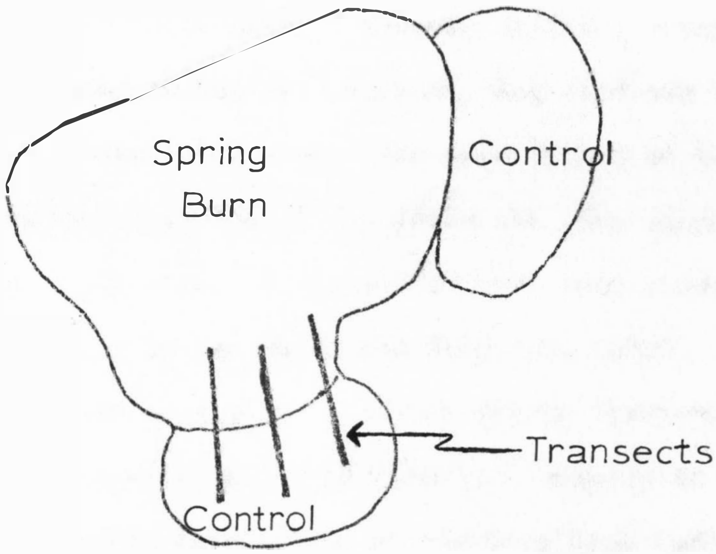


FIGURE 10. Location of Pellet Count Transects at the Wind Cave Canyon Study Area.

over the stake and a verticle photograph was taken of the vegetation directly in front of the stake. The tripod was moved back 4.5 meters (15 feet) and an oblique photograph was taken of the vegetation at that stake. All photographs were taken toward the south. Photographs were taken early in the growing season (June 7,8, and 9, 1976; May 23, 24, and 26, 1977), middle of the growing season (July 15, 16, and 19, 1976; June 28 and 29, 1977), and late in the growing season (October 2, 1976; September 27, 1977). Only one row in each treatment was duplicated each time.

CLIMATOLOGICAL DATA

Air temperature, relative humidity, wind speed, and wind direction were taken on each burning date at each study (Table 1). Monthly precipitation totals were taken from annual reports published by the National Weather Service (Appendix B).

METHODS OF ANALYSIS

Standard analysis of variance using a two-way design (treatments and rows of samples) was used to analyze pre-burn fuel load and vegetation yield data at the Rankin Ridge study area. The same method of analysis was used to analyze vegetation yields of the ponderosa pine association at the Wind Cave Canyon study area. Computer analyses were conducted by means of Statistical Analysis System (Barr and Goodnight 1972).

Standard analysis of variance using a nested design (treatments and rows of samples within treatments) was used to analyze vegetation yield data of the mixed grass prairie association at the Wind Cave Canyon study area. Computer analyses were made using a least squares method of analysis

(Harvey 1972). Treatment means were compared to control means and significance at the 90 percent confidence level was determined by an F-ratio test (Steele and Torrie 1960).

Comparisons of soil analysis data and animal feces and pellet count data were made at the 90 percent confidence level using the Student-t test.

RESULTS AND DISCUSSION

ASSUMPTIONS

At both study areas, it was assumed that the area sampled was a uniform plant association. A plant association is a kind of plant community of definite composition, presenting a uniform physiognomy and growing in uniform habitat conditions (Daubenmire 1968). A uniform soil type, climate, slope, and exposure should produce a uniform vegetation type. Differences in microclimate and grazing patterns would cause a mosaic pattern of plant species. This mosaic within a plant association could cause variation when sampling the study area. Statistically, it was assumed that the experimental error was random, independently and normally distributed about a zero mean with a common variance (Steele and Torrie 1960).

PRE-BURN FUEL LOADS

Means and standard deviations of the pre-burn fuel loads are shown in Tables 2a and 2b. Standing vegetation on the area to be burned in winter and the control area was significantly different. For all practical purposes, the actual differences in mean yields were not sufficiently great enough to affect fire behavior or regrowth of vegetation.

VEGETATION YIELDS

Rankin Ridge study area

Means and standard deviations for the 1976 and 1977 vegetation yields are shown in Tables 3 and 4, respectively. Total yields on burned and unburned areas did not vary significantly in either 1976 or 1977. Other researchers have shown that late spring burning of true prairie does not affect total yields (Anderson, et al. 1970; Ehrenreich 1959;

Table 2a

Means and Standard Deviations of Pre-burn Fuel Loads at the Rankin Ridge Study Area Sampled Nov. 11 and 12, 1976 (g/m^2)

	Winter Burn Area		Control	
	Mean	S. D.	Mean	S. D.
Mulch	195.282	30.360	209.690	30.360
Standing Yield	271.562*	0.006	265.294	0.006

* Treatment area is significantly different from the control at the 0.10 level of probability.

Table 2b

Means and Standard Deviations of Pre-burn Fuel Loads at the Rankin Ridge Study Area Sampled June 20, 1976 (g/m2)

	Mean	S. D.
Mulch	108.880	63.397
Current Green Growth	36.168	19.862
Dead Standing Yield	128.041	74.393

Table 3

Means and Standard Deviations of 1976 Vegetation Yields at the Rankin Ridge Study Area (g/m^2)

Species	Spring Burn (May 27, 1976)		Unburned Control	
	Mean	S. D.	Mean	S. D.
Little bluestem	86.62	4.62	66.13	10.27
Big bluestem	12.09	5.77	10.07	12.83
Western wheatgrass	1.28*	0.0004	2.11	0.001
Bluegrasses	41.45*	0.22	118.46	0.42
Shortgrasses	1.20	0.10	0.90	0.22
Other grasses and sedges	14.07	0.15	19.12	0.34
Forbs	50.23*	0.79	24.10	1.76
Shrubs	2.01	0.71	0.54	1.57
Total yield	209.16	4.86	241.42	10.81

* Treatment is significantly different from the control at the 0.10 level of probability.

Table 4

Means and Standard Deviations of 1977 Vegetation Yields at the Rankin Ridge Study Area (g/m^2)

Species	Spring Burn (May 27, 1976)		Winter Burn (March 1, 1977)		Control	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
Little bluestem	67.22	11.06	35.52*	1.15	65.72	6.36
Big bluestem	4.07	1.08	4.20	0.78	16.13	0.93
Western wheatgrass	1.00	0.17	3.54	0.03	2.39	0.10
Needlegrasses	0.93	0.03	2.76	0.04	0.51	0.04
Bluegrasses	31.87*	0.79	39.51*	0.51	54.60	0.65
Shortgrasses	0.76	0.003	5.18*	0.09	0.55	0.04
Annuals	44.85	89.70	0.42	0.002	0.00	0.00
Other grasses and sedges	133.86	605.53	17.02	0.92	8.52	303.23
Forbs	142.72	584.46	23.13	7.86	28.24	296.16
Shrubs	1.38	0.12	9.06	1.27	2.47	0.69
Total yield	428.66	3811.54	140.35	10.72	179.14	1911.13

* Treatment is significantly different from the control at the 0.10 level of probability.

Smith and Owensby 1973). Anderson, et al. (1970) and Smith and Owensby (1973) reported that winter and early spring burning decreased total yields. Yield reductions were thought to be caused by a slower replacement of soil moisture throughout the profile. Winter burning at the Rankin Ridge study area did not decrease total yields. There was no significant decrease in soil moisture (sampled March 1, 1977) due to burning. Soil moisture sampled in August, 1977, was significantly lower on the spring and winter burn areas compared to the unburned control (Table 13). Mention should be made that there was a snow cover within a day after burning which probably kept the ash and unburned mulch from being removed by wind.

Bluegrasses decreased on the burned treatments in both years. Western wheatgrass yield significantly decreased on the spring burn the first growing season after burning. Spring burning after cool season species initiate growth retards further growth (Anderson, et al. 1970; Holden 1975; McMurphy and Anderson 1965; Smith and Owensby 1973). This practice has been effective for reducing abundance of Kentucky bluegrass (Smith and Owensby 1973).

Forbs increased in 1976 on the spring burn. The author observed an increase in silverleaf scurfpea and slimflower scurfpea, both native legumes. A significant increase in available phosphorus (Table 13) may have been a contributing factor to the stimulation of these legumes. Other researchers have noted an increase in the abundance of native legumes on burned areas (Vogl 1974, Komarek 1976, Daubenmire 1968).

Little bluestem decreased and shortgrasses increased on the winter burn area in 1977. Smith and Owensby (1973) reported that the effects of burning on little bluestem were not clear; it responds about as well to nonburning as to any burning treatments. Fire intensity and damage to the little bluestem crowns might have contributed to the yield reduction of that species. Shortgrass increases may have been due to a reduction in competition from cool season grasses. Earlier warm-up of soils on the burn may have increased the growing period of warm season grasses. This factor could also have contributed to the increase of shortgrass yields. Smith and Owensby (1973) found that shortgrasses increased more under early spring burning than nonburning or late spring burning.

Wind Cave Canyon study area: mixed grass prairie association

Means and standard deviations for the 1976 and 1977 vegetation yields are shown in Tables 5 and 6, respectively. Total yields showed a significant decrease in both 1976 and 1977 on the spring burn. Reduced soil moisture on the burned area (Table 14) and lower precipitation in 1977 (Appendix B) could have contributed to the decrease in total yields. Also, a mixed grass prairie association accumulates less mulch than the bunchgrass subclimax. A reduction in precipitation would have a greater effect on the burned area because burning of the mulch would increase the exposure of the soil and result in greater evaporation (Launchbaugh 1973).

Needleandthread, western wheatgrass, and shortgrass yields were significantly greater on the burned area in 1976 compared with the unburned area. Western wheatgrass and shortgrass yields on the burned area were also significantly higher in 1977, while needleandthread, bluegrasses, and sedges decreased.

Table 5

Means and Standard Deviations of 1976 Vegetation Yields of the Mixed Grass Prairie Association at the Wind Cave Canyon Study Area (g/m^2)

Species	Spring Burn (April 21, 1976)		Unburned Control	
	Mean	S. D.	Mean	S. D.
Western Wheatgrass	17.51*	21.50	6.25	6.03
Needleandthread	91.20*	52.04	60.86	32.71
Green needlegrass	0.01*	0.06	7.46	14.82
Bluegrasses	1.50*	5.79	45.70	46.40
Shortgrasses	15.91*	14.54	2.90	3.55
Other grasses and sedges	11.36	16.76	11.01	15.53
Forbs	23.77	39.46	42.87	21.43
Shrubs	0.40	1.07	0.38	1.48
Total yield	127.36*	50.28	177.44	15.87

* Treatment is significantly different from the control at the 0.10 level of probability.

Table 6

Means and Standard Deviations of 1977 Vegetation Yields of the Mixed Grass Prairie Association at the Wind Cave Canyon Study Area (g/m^2)

Species	Spring Burn (April 21, 1976)		Unburned Control	
	Mean	S. D.	Mean	S. D.
Western Wheatgrass	13.48*	13.15	4.31	5.41
Needleandthread	32.89*	17.89	54.38	33.06
Green needlegrass	0.73	2.84	7.71	18.11
Bluegrasses	2.41*	9.26	19.15	31.30
Shortgrasses	11.62*	15.10	2.56	2.31
Other grasses and sedges	4.26	4.66	9.97	9.91
Forbs	12.57	16.42	13.71	11.09
Shrubs	9.30	0.86	0.00	0.00
Total yield	77.86*		104.52	22.26

* Treatment is significantly different from the control at the 0.10 level of probability.

Bluegrass yield reductions and increased yields of shortgrasses could probably be attributed to the same factors influencing those species on the Rankin Ridge study area. The author observed a stimulation of flowering (infloresence size and number) of needleandthread during the first year after burning, which probably contributed to the increase in yield that year. The decrease in needleandthread and sedges in 1977 may have been affected by the reduction in precipitation during 1977 (Appendix B). The increase in western wheatgrass will be discussed later.

Wind Cave Canyon study area: ponderosa pine association

Means and standard deviations for the 1976 and 1977 vegetation yields are shown in Tables 7 and 8, respectively. On the burned area, there were significant increases in total yield and forbs in 1976; little bluestem in 1977; and sedges in both years.

The elimination of the dense pine cover provided space for the potential increase of every herbaceous component. Sampling variability probably accounts for the fact that more of the vegetative components did not show a significant increase (Fig. 11, 12, and 13).

PLANT HEIGHT AND DENSITY

Plant density at the Rankin Ridge study area

Percentage composition and estimated densities of major species are shown in Table 9. No statistical comparisons were made between treatments. Research has reported both increases and decreases in plant densities due to burning. Countryman and Cornelius (1957) reported a reduction in density of perennial grasses as a result of changes in microclimate and closer grazing due to removal of brush cover by fire. Lewis and Harshbarger (1976) reported an increase in the percentage of

Table 7

Means and Standard Deviations of 1976 Vegetation Yields of the Ponderosa Pine Association at the Wind Cave Canyon Study Area (g/m^2)

Species	Spring Burn (April 21, 1976)		Unburned Control	
	Mean	S. D.	Mean	S. D.
Little bluestem	9.20	0.42	1.23	0.84
Big bluestem	60.82	1.22	2.16	2.44
Needlegrasses	41.22	9.60	29.65	19.19
Bluegrasses	9.81	0.64	2.45	1.29
Shortgrasses	5.30	0.004	1.96	0.008
Other grasses and sedges	31.96*	0.09	4.36	0.19
Forbs	104.23*	0.86	11.87	1.71
Shrubs	9.61	0.94	0.74	1.88
Total yield	272.14*	6.57	54.20	13.14

* Treatment is significantly different from the control at the 0.10 level of probability.

Table 8

Means and Standard Deviations of 1977 Vegetation Yields of the Ponderosa Pine Association at the Wind Cave Canyon Study Area (g/m^2)

Species	Spring Burn (April 21, 1976)		Unburned Control	
	Mean	S. D.	Mean	S. D.
Little bluestem	1.72*	0.00007	0.65	0.00014
Big bluestem	30.68	0.62	4.92	1.23
Wheatgrasses	9.15	0.12	7.05	0.24
Needlegrasses	17.98	0.28	9.52	0.56
Bluegrasses	3.88	0.07	0.94	0.14
Shortgrasses	7.21	0.01	2.25	0.20
Other grasses and sedges	11.43*	0.0002	2.92	0.0005
Forbs	18.64	0.72	4.72	1.44
Shrubs	0.10	0.009	1.04	0.02
Total yield	100.67	1.76	21.45	3.53

* Treatment is significantly different from the control at the 0.10 level of probability.

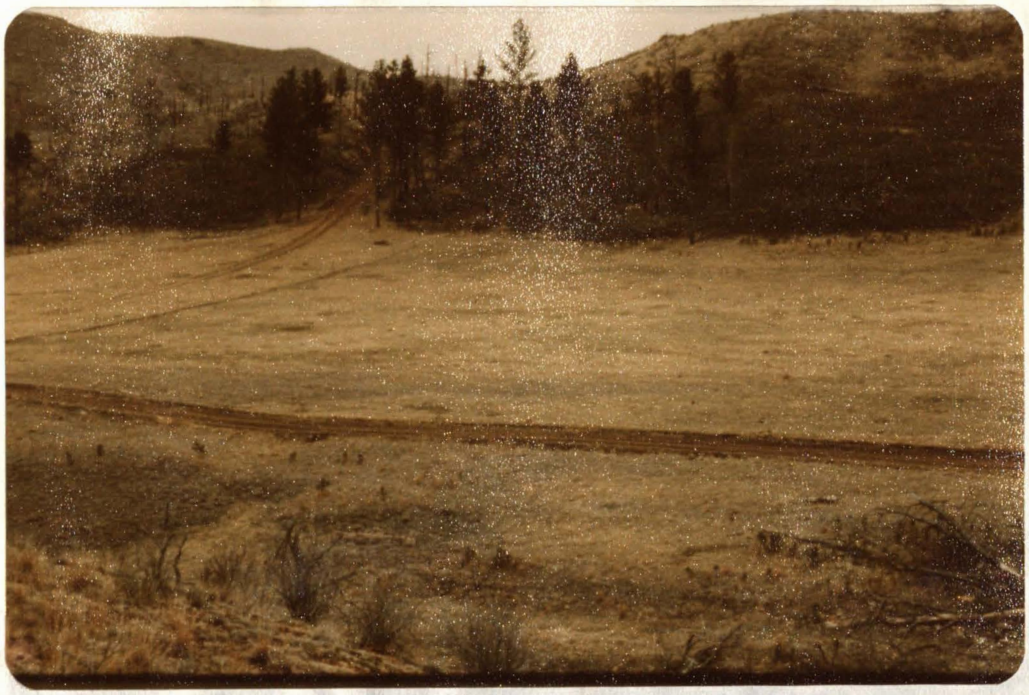


FIGURE 11. Ponderosa Pine Association at the Wind Cave Canyon Study Area Before Burning. The area to be burned is right of the fire trail; the control is left of the fire trail. April 21, 1976.

FIGURE 12. Ponderosa Pine Association at the Wind Cave Canyon Study Area After Burning. June 8, 1976.

FIGURE 13. Ponderosa Pine Association at the Wind Cave Canyon Study Area After Burning. September 27, 1977.

Table 9

Percentage Composition and Estimated Density of Major Species at the Rankin Ridge Study Area (1977)

	Control		Spring Burn		Winter Burn	
	Transect 1	Transect 2	Transect 1	Transect 2	Transect 1	Transect 2
Total Plant Density*	74.44	73.96	83.37	19.63	1403.74	1247.95
Bluegrasses						
Composition (%)	59.50	62.00	45.00	32.00	52.00	43.50
Density	44.29	45.86	37.52	6.28	729.95	542.86
Little bluestem						
Composition (%)	14.25	14.75	21.25	18.00	11.00	8.00
Density	10.61	10.91	17.72	3.53	154.41	99.84
Big bluestem						
Composition (%)	3.25	10.00	10.50	19.25	1.50	1.00
Density	2.42	7.40	8.75	3.78	21.06	12.48
Sedges						
Composition (%)	20.50	10.00	17.75	20.25	25.00	29.50
Density	15.26	7.40	14.80	3.98	350.94	368.15
Forbs						
Composition (%)	1.50	1.75	4.75	7.00	6.00	5.50
Density	1.12	1.29	3.96	1.37	84.22	68.64

* Densities are reported as number of plants per square meter.

ground cover with most burning treatments. They also reported that winter burning produced the most significant increase in cover. Total plant density on the winter burn at the Rankin Ridge study area was almost 15 times greater than the densities on the unburned control or spring burn.

Western wheatgrass density at the Rankin Ridge and Wind Cave Canyon study areas

Means and standard deviations of plant heights and densities of western wheatgrass are shown in Table 10. On the Wind Cave Canyon mixed grass prairie association, plant density significantly increased while plant height significantly decreased on the burned area. Western wheatgrass yields also increased in both years on the burned area. Increased yields could have resulted from a greater density compensating for the reduced plant height.

Western wheatgrass is capable of reproducing from rhizomes which are protected from fire. Launchbaugh (1973) reported that early burning or early mowing and raking more than doubled plant shoot numbers of switchgrass compared with late burning or late mowing and raking or no treatment. Switchgrass also has coarse, scaly rhizomes. Rhizome reproduction is reliable in dry conditions because the established root systems of the mother plant provides moisture to new shoots. Thus, rhizomatous plants have a competitive advantage over seedlings (Stoddart, et al. 1975). Rhizomatous plants have another competitive advantage: they can take advantage of space as soon as openings are created. They do not have to wait for the next growing season as do plants that depend on reproduction by seed. Removal of mulch by burning probably created a drier surface soil and resulted in a poor microclimate for seed reproduction. Decreases in

Table 10

Means, Standard Deviations, and Sample Sizes of Plant Height (cm) and Density (plants/m^2) of Western Wheatgrass (Agropyron smithii) sampled in 1977

		Wind Cave Canyon Study Area		Rankin Ridge Study Area		
		Spring Burn	Control	Spring Burn	Winter Burn	Control
Plant Density	Mean	99.99[a]	17.87	8.08	18.73[a]	10.23
	S. D.	88.14	22.35	20.14	25.26	24.60
	Sample Size[b]	50	50	100	100	100
Plant Height	Mean	24.16[a]	28.01	20.02[a]	18.01[a]	27.73
	S. D.	4.65	5.50	4.35	3.68	6.02
	Sample Size[c]	100	100	100	100	100

[a] Treatments are significantly different from the control at the 0.10 level of probability.

[b] Sample size is reported as the number of frames used in sampling.

[c] Sample size is reported as the number of plants measured.

other vegetative components would create growing space for rhizomatous species.

At the Rankin Ridge study area, western wheatgrass density significantly increased on the winter burn. Both burning treatments reduced plant height. A decrease in 1976 yield of western wheatgrass on the spring burn was the only significant yield change at the Rankin Ridge study area. Even though plant density increased on the winter burn, the increase was apparently not sufficiently great enough to compensate for reduced plant height. Thus, western wheatgrass yield did not change.

Western wheatgrass yields on the spring burn were reduced in 1976, probably because of the time of burning. Burning in late May, when meristematic tissue is actively growing and extended above the soil surface, would be expected to be hazardous to the growth of the plant.

Ponderosa pine density at the Rankin Ridge and Wind Cave Canyon study areas

Means and standard deviations of ponderosa pine density are shown in Table 11. Means and standard deviations of tree height are shown in Table 12. At the Wind Cave Canyon study area, pine density on the burned area was approximately equal to that of the control. In general, pine density on the lower slope was less than that on the upper slope. Tree height averaged greater than half a meter but less than a meter.

Density of the pine enchroachment at the Rankin Ridge study area was much less than density of the "doghair" at the Wind Cave Canyon study area (less than one tree per square meter). Tree height at the Rankin Ridge study area was approximately equal to tree height at the Wind Cave Canyon study area.

Table 11

Means and Standard Deviations of Density of Ponderosa Pine (*Pinus ponderosa*)

	Wind Cave Canyon Study Area Spring Burn		Wind Cave Canyon Study Area Control	Rankin Ridge Study Area Winter Burn
	Mean[a]	S. D.		
Row 1 (lower slope)	19.45[b]	11.72	13.07	0.16
Row 2	11.56	2.58	20.38	0.13
Row 3	9.61	6.53	10.40	0.10
Row 4 (upper slope)	7.54	6.22	8.48	0.12

[a] Density values shown for the spring burn at the Wind Cave Canyon study area are a mean of three transects.

[b] Densities are reported as number of trees per square meter.

Table 12

Means and Standard Deviations of Height (m) of Ponderosa Pine (*Pinus ponderosa*)

	Wind Cave Canyon Study Area Spring Burn		Wind Cave Canyon Study Area Control		Rankin Ridge Study Area Winter Burn	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
Row 1 (lower slope)	0.74	0.35	0.75	0.34	0.70	0.18
Row 2	0.76	0.29	0.64	0.32	0.73	0.24
Row 3	0.83	0.29	0.89	0.38	0.64	0.20
Row 4 (upper slope)	0.81	0.35	0.70	0.34	0.77	0.24

Of the trees that were measured, 95 percent on the east section, 100 percent on the middle section, and 97 percent on the west section were killed by burning at the Wind Cave Canyon study area. At the Rankin Ridge study area, 65 percent of the trees measured were killed. Lindenmuth (1962) reported that the proportion of potential crop trees damaged and killed by fire increased with higher stand density and with fire intensity, and decreased with increasing tree size. He also stated that of the total number of trees damaged plus killed, a larger percentage was killed in the small sizes.

SOIL ANALYSES

Soil moisture

Soil moisture sampled in August, 1977, at the Rankin Ridge study area was significantly lower on both burning than on control (Table 13). Decreases were significant at both sampling depths. At the Wind Cave Canyon study area, mixed grass prairie association post-burn soil moisture samples at the 0-1 cm. depth were significantly lower than pre-burn samples (Table 14). There was also significantly less soil moisture on the burned area compared to the control in August, 1977, at both depths. Removal of mulch by burning exposes more surface area resulting in greater evaporation and a drier surface soil (Daubenmire 1968).

At the Wind Cave Canyon ponderosa pine association (Table 15), post-burn samples were significantly lower than pre-burn samples on the lower slope (1-3 cm. depth) and mid-slope (0-1 cm. and 1-3 cm. depth). Soil moisture sampled in August, 1977, were significantly lower than pre- and post-burn samples on the upper and mid-slope (0-1 cm. depth). Decreases in soil moisture could have been attributed to an increase in runoff.

Table 13

Soils Data of the Rankin
Ridge Study Area

Location and Sampling Date	Depth	% Moisture		pH		% Organic Matter	
		Mean	S. D.	Mean	S. D.	Mean	S. D.
Winter Burn							
March 1, 1977	0-1 cm.	16.87	7.83			16.57	6.02
(Pre-burn)	1-3 cm.	13.97	4.85			10.83	3.12
March 1, 1977	0-1 cm.	19.03	0.01			15.11	1.96
(Post-burn)	1-3 cm.	14.93	3.01			14.96	3.78
August 24, 1977	0-1 cm.	19.37[b]	5.28			14.15[b]	4.69
	1-3 cm.	24.38[b]	4.22			11.31	2.60
Spring Burn							
April 20, 1976	0-1 cm.	31.17	4.80	5.80	0.10	13.29	4.31
(Pre-burn)	1-3 cm.	28.17	11.33	5.80	0.10	11.66	6.74
May 28, 1977	0-1 cm.	46.20[a]	9.63	5.73	0.15	14.01	2.43
(Post-burn)	1-3 cm.	27.83	6.52	5.73	0.15	6.12	0.74
August 24, 1977	0-1 cm.	21.62[b]	5.86			17.47	5.00
	1-3 cm.	18.12[b]	6.42			9.48[b]	1.46
Control							
March 1, 1977	0-1 cm.	16.07	1.46			19.39	5.32
	1-3 cm.	16.03	7.26			9.71	0.97
August 24, 1977	0-1 cm.	44.07	5.40			20.19	1.35
	1-3 cm.	34.03	4.32			12.14	1.00

[a] Pre- and post burn samples are significantly different at the 0.10 level of probability.
[b] Treatments are significantly different from the control at the 0.10 level of probability.

Table 13 (Continued)

Location and Sampling Date	Depth	Ammonium (ppm)		Nitrate (ppm)		% Total Nitrogen	
		Mean	S. D.	Mean	S. D.	Mean	S. D.
Winter Burn							
March 1, 1977	0-1 cm.	0.09	0.05	0.04	0.02	0.69	0.24
(Pre-burn)	1-3 cm.	0.08[b]	0.02	0.03	0.01	0.49	0.15
March 1, 1977	0-1 cm.	0.07	0.01	0.02	0.01	0.56	0.17
(Post-burn)	1-3 cm.	0.07	0.01	0.02[a]	0.01	0.36	0.09
August 24, 1977	0-1 cm.	0.05[b]	0.01	0.07	0.03	0.59[b]	0.17
	1-3 cm.	0.05[b]	0.01	0.08	0.01	0.49[b]	0.14
Spring Burn							
April 20, 1976	0-1 cm.	15.31	2.53	11.45	1.22	0.52	0.15
(Pre-burn)	1-3 cm.	12.77	8.82	11.96	6.31	0.50	0.23
May 28, 1976	0-1 cm.	17.26	2.74	21.74	11.86	0.58	0.04
(Post-burn)	1-3 cm.	28.06	27.74	6.04	5.10	0.32[a]	0.02
August 24, 1977	0-1 cm.	0.29	0.28	0.22	0.22	0.67[b]	0.11
	1-3 cm.	0.38	0.30	0.08	0.04	0.44[b]	0.05
Control							
March 24, 1977	0-1 cm.	0.18	0.10	0.56	0.04	0.81	0.21
	1-3 cm.	0.03	0.01	0.02	0.02	0.45	0.04
August 24, 1977	0-1 cm.	0.13	0.02	0.26	0.16	0.87	0.07
	1-3 cm.	0.11	0.03	0.07	0.05	0.54	0.04

[a] Pre- and post-burn samples are significantly different at the 0.10 level of probability.
[b] Treatments are significantly different from the control at the 0.10 level of probability.

Table 13 (Continued)

Location and Sampling Date	Depth	Available PO_4-P (ppm)		Available P (ppm)	
		Mean	S. D.	Mean	S. D.
Winter Burn					
March 1, 1977	0-1 cm.			17.53	4.72
(Pre-burn)	1-3 cm.			9.42	1.65
March 1, 1977	0-1 cm.			12.85	2.33
(Post burn)	1-3 cm.			8.30	3.28
August 24, 1977	0-1 cm.			10.43	2.93
	1-3 cm.			12.60	7.98
Spring Burn					
April 20, 1976	0-1 cm.	3.81	1.64	13.52	3.94
(Pre-burn)	1-3 cm.	3.49	4.67	11.45	7.41
May 28, 1976	0-1 cm.	6.96[a]	1.38	24.93	3.38
(Post-burn)	1-3 cm.	1.73	1.31	9.27	3.38
August 24, 1977	0-1 cm.			17.53	4.06
	1-3 cm.			13.27	5.27
Control					
March 24, 1977	0-1 cm.			16.98	5.10
	1-3 cm.			7.22	0.98
August 24, 1977	0-1 cm.			13.10	4.69
	1-3 cm.			8.90	6.70

[a] Pre- and post-burn samples are significantly different at the 0.10 level of probability.

Table 14

Soils Data of the Mixed Grass Prairie Association
at the Wind Cave Canyon Study Area

Location and Sampling Date	Depth	% Moisture		pH		% Organic Matter	
		Mean	S. D.	Mean	S. D.	Mean	S. D.
Spring Burn							
April 20, 1076	0-1 cm.	29.60	4.16	6.70	0.36	6.75	0.74
(Pre-burn)	1-3 cm.	30.37	2.71	6.83	0.15	4.49	0.57
April 22, 1976	0-1 cm.	21.27[a]	2.72	6.70	0.10	7.76	0.92
(Post-burn)	1-3 cm.	33.37	23.95	6.90	0.20	4.99	0.09
August 24, 1977	0-1 cm.	3.42[b]	0.448			5.32[b]	0.78
	1-3 cm.	6.15[b]	0.912			5.07	0.83
Control							
August 24, 1977	0-1 cm.	12.40	4.29			6.61	0.42
	1-3 cm.	18.03	2.98			5.69	0.52

[a] Pre- and post-burn samples are significantly different at the 0.10 level of probability.
[b] Treatments are significantly different from the control at the 0.10 level of probability.

Table 14 (Continued)

Location and Sampling Date	Depth	Ammonium (ppm)		Nitrogen (ppm)		% Total Nitrogen	
		Mean	S. D.	Mean	S. D.	Mean	S. D.
Spring Burn							
April 20, 1976	0-1 cm.	3.81	3.36	9.91	1.81	0.31	0.03
(Pre-burn)	1-3 cm.			8.28	9.80	0.25	0.02
April 22, 1976	0-1 cm.	5.24	4.99	13.57	4.02	0.30	0.02
(Post-burn)	1-3 cm.	1.91	3.31	12.61	11.53	0.34	0.17
August 24, 1977	0-1 cm.	0.05	0.01	0.05	0.02	0.30	0.05
	1-3 cm.	0.05	0.01	0.04	0.02	0.31	0.04
Control							
August 24, 1977	0-1 cm.	0.06	0.02	0.04	0.02	0.37	0.03
	1-3 cm.	0.07	0.01	0.04	0.01	0.32	0.05

Table 14 (Continued)

Location and Sampling Date	Depth	Available PO_4-P (ppm)		Available P (ppm)	
		Mean	S. D.	Mean	S. D.
Spring Burn					
April 20, 1976	0-1 cm.	1.35	0.34	18.09	2.96
(Pre-burn)	1-3 cm.	0.57	0.10	8.53	0.73
April 22, 1976	0-1 cm.	1.51	0.33	17.23	3.34
(Post-burn)	1-3 cm.	0.37	0.13	7.03[a]	1.01
August 24, 1977	0-1 cm.			27.13[b]	1.01
	1-3 cm.			14.98[b]	2.82
Control					
August 24, 1977	0-1 cm.			7.63	1.22
	1-3 cm.			4.45	0.13

[a] Pre- and post-burn samples are significantly different at the 0.10 level of probability.
[b] Treatments are significantly different from the control at the 0.10 level of probability.

Table 15

Soil Data of the Ponderosa Pine Association
at the Wind Cave Canyon Study Area

Location and Sampling Date	Depth	% Moisture		pH		% Organic Matter	
		Mean	S. D.	Mean	S. D.	Mean	S. D.
Lower Slope							
April 20, 1976	0-1 cm.	39.47	12.10	7.50	0.17	14.87	2.32
(Pre-burn)	1-3 cm.	36.0	4.69	7.60	0.10	10.70	1.65
April 22, 1976	0-1 cm.	25.47	2.51	7.60	0.10	12.75	0.60
(Post-burn)	1-3 cm.	26.2[a]	2.57	7.63	0.06	10.23	0.43
August 24, 1977	0-1 cm.	25.72	6.87			14.90[b]	1.00
	1-3 cm.	26.37	2.11			11.56[b]	0.45
Mid Slope							
April 20, 1976	0-1 cm.	49.13	8.60	7.03	0.23	15.90	6.13
(Pre-burn)	1-3 cm.	38.3	3.25	7.27	0.06	10.75	1.38
April 22, 1976	0-1 cm.	27.33[a]	3.19	7.23	0.12	12.49	0.72
(Post-burn)	1-3 cm.	25.19[a]	2.91	7.60[a]	0.10	10.63	0.21
August 24, 1977	0-1 cm.	18.03[b]	5.11			14.96	3.93
	1-3 cm.	24.35	6.02			12.23	2.75
Upper Slope							
April 20, 1976	0-1 cm.	44.60	6.90	7.63	0.06	15.34	1.51
(Pre-burn)	1-3 cm.	40.67	4.26	7.67	0.12	12.64	0.76
April 22, 1976	0-1 cm.	36.43	4.38	7.60	0.10	15.23	1.78
(Post-burn)	1-3 cm.	37.10	7.55	7.70	0.01	13.09	2.25
August 24, 1977	0-1 cm.	20.73[b]	3.22			14.43	3.10
	1-3 cm.	27.33	6.14			13.93	3.75

[a] Pre-and post-burn samples are significantly different at the 0.10 level of probability.
[b] August samples are significantly different from pre- and post-burn samples at the 0.10 level.

Table 15 (Continued)

Location and Sampling Date	Depth	Ammonium (ppm)		Nitrate (ppm)		% Total Nitrogen	
		Mean	S. D.	Mean	S. D.	Mean	S. D.
Lower Slope							
April 20, 1976	0-1 cm.	3.46	2.96	3.38	2.07	0.65	0.06
(Pre-burn)	1-3 cm.	5.50	0.81	6.63	6.03	0.49	0.04
April 22, 1976	0-1 cm.	23.34[a]	6.70	8.20	3.93	0.53[a]	0.02
(Post-burn)	1-3 cm.	1.06[a]	1.83	3.42	1.92	0.47	0.02
August 24,1977	0-1 cm.	0.05[b]	0.02	0.06[b]	0.01	0.64[b]	0.06
	1-3 cm.	0.05	0.02	0.04[b]	0.01	0.52	0.04
Mid Slope							
April 20, 1976	0-1 cm.	1.68	1.51	9.95	5.59	0.61	0.10
(Pre-burn)	1-3 cm.	2.70	3.44	5.64	4.57	0.51	0.06
April 22, 1976	0-1 cm.	16.26	12.52	8.05	4.14	0.53	0.04
(Post-burn)	1-3 cm.	3.08	2.84	12.70	3.63	0.48	0.01
August 24, 1977	0-1 cm.	0.07[b]	0.03	0.04[b]	0.01	0.63	0.08
	1-3 cm.	0.05	0.01	0.05[b]	0.01	0.46	0.11
Upper Slope							
April 20, 1976	0-1 cm.	3.64	1.39	7.47	3.15	0.68	0.03
(Pre-burn)	1-3 cm.	1.99	2.17	4.86	6.48	0.61	0.12
April 22, 1976	0-1 cm.	4.28	3.99	18.81[a]	5.51	0.65	0.06
(Post-burn)	1-3 cm.	1.05	1.82	12.14	10.85	0.58	0.09
August 24, 1977	0-1 cm.	0.03	0.01	0.09[b]	0.03	0.70	0.14
	1-3 cm.	0.03	0.01	0.08	0.02	0.64	0.19

[a] Pre- and post-burn samples are significantly different at the 0.10 level of probability.
[b] August samples are significantly different from pre- and post-burn samples at the 0.10 level of probability.

Table 15 (Continued)

Location and Sampling Date	Depth	Available PO_4^-P (ppm) Mean	S. D.	Available P (ppm) Mean	S. D.
Lower Slope					
April 20, 1976	0-1 cm.	4.59	2.58	23.39	5.85
(Pre-burn)	1-3 cm.	2.67	1.01	10.17	3.61
April 22, 1976	0-1 cm.	4.58	1.49	16.25	5.09
(Post-burn)	1-3 cm.	2.09	0.12	6.30	0.17
August 24, 1977	0-1 cm.			11.95	2.31
	1-3 cm.			7.17	1.69
Mid Slope					
April 20, 1976	0-1 cm.	4.31	1.78	40.067	12.40
(Pre-burn)	1-3 cm.	3.23	1.17	28.223	5.87
April 22, 1976	0-1 cm.	4.90	1.78	37.633	4.88
(Post-burn)	1-3 cm.	3.37	1.01	20.167	6.54
August 24, 1977	0-1 cm.			42.83	6.56
	1-3 cm.			33.17	8.92
Upper Slope					
April 20, 1976	0-1 cm.	6.51	1.51	31.53	8.83
(Pre-burn)	1-3 cm.	2.43	0.36	12.57	7.56
April 22, 1976	0-1 cm.	5.73	2.48	15.93[a]	1.10
(Post-burn)	1-3 cm.	2.52	0.61	6.23	4.29
August 24, 1977	0-1 cm.			19.45	8.10
	1-3 cm.			14.40	6.84

[a] Pre- and post-burn samples are significantly different at the 0.10 level of probability.

Other researchers have reported increases in runoff or watershed yields after pine removal (Gary 1975, Orr and Vanderheide 1973).

pH

The only significant difference in pH measurements occurred at the ponderosa pine associaiton (Table 15). At the mid-slope sample area, post-burn pH values (1-3 cm. depth) were significantly higher compared to pre-burn samples. On all treatments, post-burn samples had higher pH values compared to pre-burn samples, but differences were too small to be significant.

When organic matter is burned, the mineral substances are released as oxides or carbonates that usually have an alkaline reaction. Thus, the pH value increases (Viro 1974). There may not have been enough organic matter oxidized on the study areas to cause a significant difference in pH values.

Other researchers have reported variable pH difference on burned and unburned areas. Vlamis, et al. (1955) reported a rise in pH on neutral soils after burning, but not on acid soils. Marshall and Averill (1928) reported that acid forest soils became alkaline after wildfires. Mayland (1967) reported that burned soils averaged 0.5 units higher in pH than unburned soils. Owensby and Wyrill (1973) found that winter and mid-spring burning resulted in higher pH values than late spring burning or nonburning. Christensen (1976) did not find significant changes in pH.

Organic matter

Soil organic matter sampled in August, 1977, was significantly lower on the winter burn (0-1 cm. depth) and spring burn (1-3 cm. depth) compared to the control at the Rankin Ridge study area (Table 13). At the Wind Cave Canyon study area, mixed grass prairie association samples (0-3 cm. depth) were significantly lower in organic matter compared to the control in August, 1977 (Table 14). Samples collected in August, 1977, on the lower slope of the ponderosa pine association were significantly higher in organic matter compared to post-burn samples (Table 15).

Grassland fires are seldom hot enough to directly oxidize organic matter that lies deeper than a few millimeters in the soil profile. Grasslands also burn quickly. Thus, the fire intensity is never very great at one point. Reductions in organic matter may have resulted from stimulated microbial activity and temporary elimination of the humus source (Daubenmire 1968).

Debyle (1976) and Packer and Williams (1976) reported decreases in soil organic matter due to burning after logging. Owensby and Wyrill (1976) found that winter and mid-spring burning resulted in higher organic matter than late spring burning or nonburning.

Ammonium (NH_4+), nitrate (NO_3^-), and total nitrogen (N)

The winter burn at the Rankin Ridge study area was significantly lower in NH_4^+ and total N compared to the control in August 1977 (Table 13). Decreases were significant at both depths. Post-burn samples on the winter burn were significantly lower in NO_3^- (1-3 cm. depth) compared to pre-burn samples.

Post-burn samples on the spring burn at the Rankin Ridge study area were significantly lower in total N (1-3 cm. depth) compared to pre-burn samples (Table 13). Total N was also significantly lower on the spring burn compared to the control in August, 1977, at both depths.

At the Wind Cave Canyon study area, post-burn samples on the lower slope of the ponderosa pine association were lower NH_4^+ and total N at the 0-1 cm. depth and higher in NH_4^+ at the 1-3 cm. depth compared to pre-burn samples (Table 15). Post-burn samples on the upper slope were significantly higher in NO_3^- (0-1 cm. depth) compared to pre-burn samples. Samples collected in August, 1977, from all parts of the slope were significantly lower in NO_3^- compared to pre- and post-burn samples.

Lower levels of NH_4^+ and NO_3^- in the August samples may have reflected increases in plant uptake, especially on the ponderosa pine association. The higher level of NO_3^- occurred in the area of shrubs at the ponderosa pine association, and increased uptake by forbs may not have been an important factor.

Other researchers have reported increases in nitrogen due to burning (Vlamis, et al. 1955; Vlamis and Gowans 1961). Later research showed that the total amount of nitrogen decreased, but burning increased the nitrogen concentration of residual materials (Knight 1966). Studies have showed that 25 to 60 percent of the nitrogen is volatilized during burning (Debell and Ralston 1970, Knight 1966, Viro 1974). Debell and Ralston (1970) reported an increase in NO_3-N concentrations. Christensen (1976) reported increases in ammonia on burned areas.

Available phosphate (PO_4^-) and phosphorus (P)

Post-burn samples were significantly higher in available phosphate (0-1 cm. depth) compared to pre-burn samples on the spring burn at the

Rankin Ridge study area (Table 13). Post-burn samples were significantly lower in available phosphorus (0-1 cm. depth) compared to pre-burn samples on the upper slope of the ponderosa pine association at the Wind Cave Canyon study area (Table 15). Post-burn samples (1-3 cm. depth) were significantly lower in available phosphorus compared to pre-burn samples on the mixed grass prairie association (Table 14). Samples collected on the mixed grass prairie association burn in August, 1977, were significantly higher in available phosphorus compared to the control. Differences were significant at both depths.

The available phosphorus released by burning may not have been taken up by plants as readily as NH_4^+ and NO_3^-. This could have contributed to higher phosphorus levels on the mixed grass prairie association. Variation of the means was high due to either the sampling procedure and/or the analysis procedure, and could have contributed to the variability of the results.

Other researchers have reported increases in total phosphorus (Debyle 1976; Jordan 1965; Vlamis, et al., 1955; Vlamis and Gowans 1961). Viro (1974) found that after burning, phosphorus was found to a large extent as water-soluble alkali phosphate. White and Gartner (1975) reported that increases in available phosphate probably resulted from organic matter in the soil and not from surface plant residue.

ANIMAL USE

Grazing estimates: stubble heights and percentage of plants grazed

There was no significant difference between the height of little bluestem on the control and under the exclosure cages on the spring burn at the Rankin Ridge study area in 1976 (Table 16). Plant heights were significantly shorter on the burned area outside the cages (Fig. 14). A greater percentage of little bluestem plants were grazed on the spring burn than on the control (Table 17).

Big bluestem was significantly shorter on the control than inside the cages on the burned area (Table 16). Big bluestem outside the cages on the burned area was significantly shorter than on both the control and inside the cages (Fig. 14). A greater percentage of big bluestem plants were grazed on the spring burn than on the control (Table 17).

This data would suggest that there was intense use of the burned area in 1976. Little bluestem was highly preferred by bison and other ungulates where it had been burned. There was little grazing use of little bluestem on the control. Big bluestem was preferred on the burned area, but was also selected for on the control.

At the Wind Cave Canyon study area, needleandthread was significantly taller on the control compared to either inside or outside the cages on the burned area (Table 18). Grazing use was detected on the burned area outside the cages (Fig. 15). Little bluestem was also significantly taller on the control compared to either inside or outside the cages on the burned area (Table 18). No significant difference in plant height of little bluestem between inside and outside the cages on the burned area was detected (Fig. 15).

Table 16

Means and Standard Deviations of Plant Heights (cm) at the Rankin Ridge Study Area for 1976 Grazing Estimates

	Spring Burn				Control	
	Inside Cages		Outside Cages			
Species	Mean	S. D.	Mean	S. D.	Mean	S. D.
Little bluestem	19.05[a]	3.22	9.60[c]	2.65	20.31	5.19
Big bluestem	39.90[ab]	9.80	12.27[c]	4.67	28.61	10.82

[a] Plant height inside the cages is significantly different from outside the cages at the 0.10 level of probability.

[b] Plant height inside the cages is significantly different from the control at the 0.10 level of probability.

[c] Plant height outside of the cages significantly different from the control at the 0.10 level of probablility.

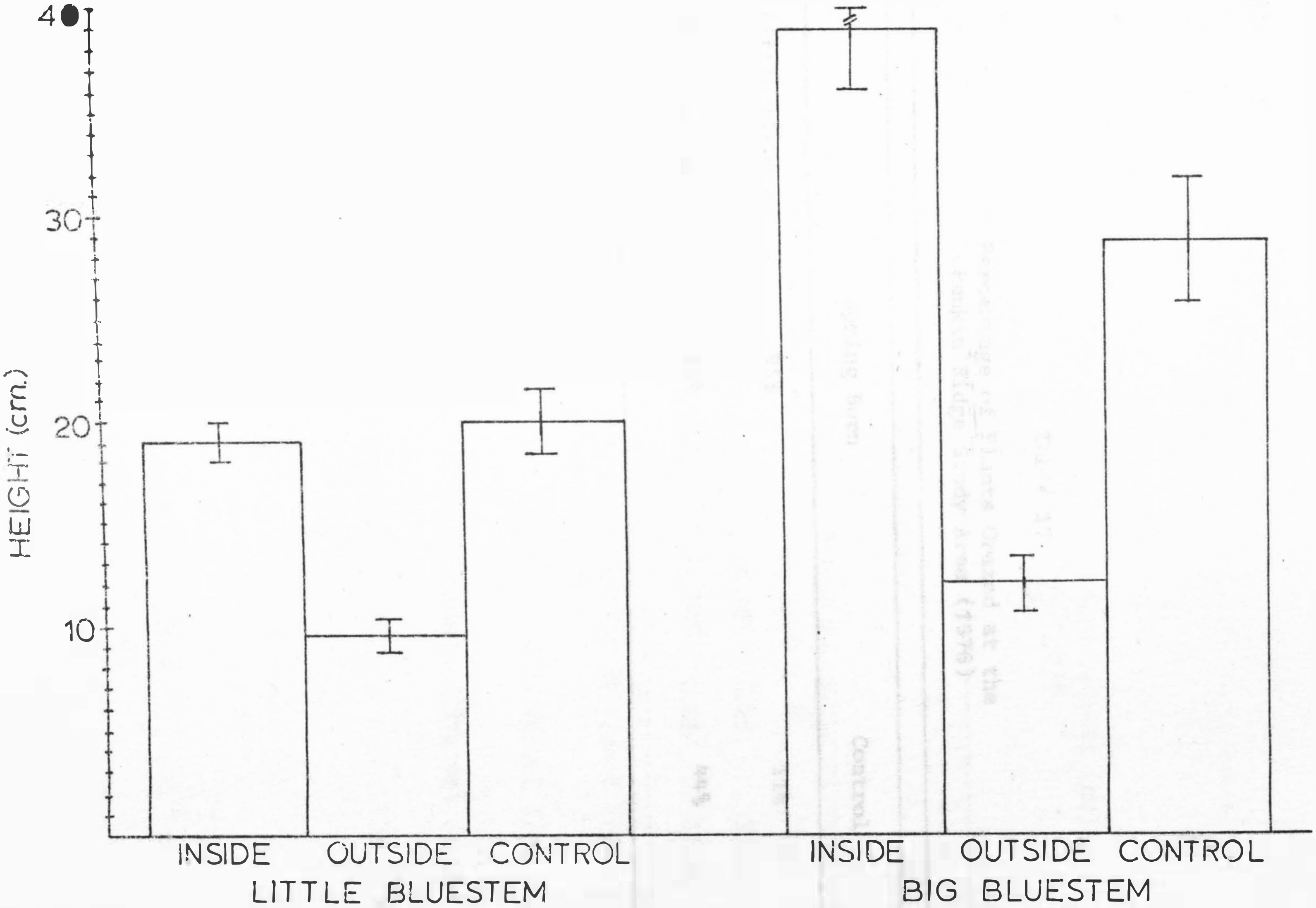


FIGURE 14. Plant Heights for 1976 Grazing Estimates at the Rankin Ridge Study Area. (Means are shown with 90% confidence intervals.)

Table 17

Percentage of Plants Grazed at the Rankin Ridge Study Area (1976)

	Spring Burn	Control
Little bluestem	95%	11%
Big bluestem	98%	44%

Table 18

Means and Standard Deviations of Plant Heights (cm) at the Wind Cave Canyon Study Area for 1976 Grazing Estimates

	Spring Burn				Control	
	Inside Cages		Outside Cages			
Species	Mean	S. D.	Mean	S. D.	Mean	S. D.
Needleandthread	22.44[ab]	3.57	20.52[c]	5.20	30.24	5.96
Little bluestem	17.08[b]	2.76	16.89[c]	1.89	23.70	3.21

[a] Plant height inside the cages is significantly different from outside the cages at the 0.10 level of probability.

[b] Plant height inside the cages is significantly different from the control at the 0.10 level of probability.

[c] Plant height outside the cages is significantly different at the 0.10 level of probability.

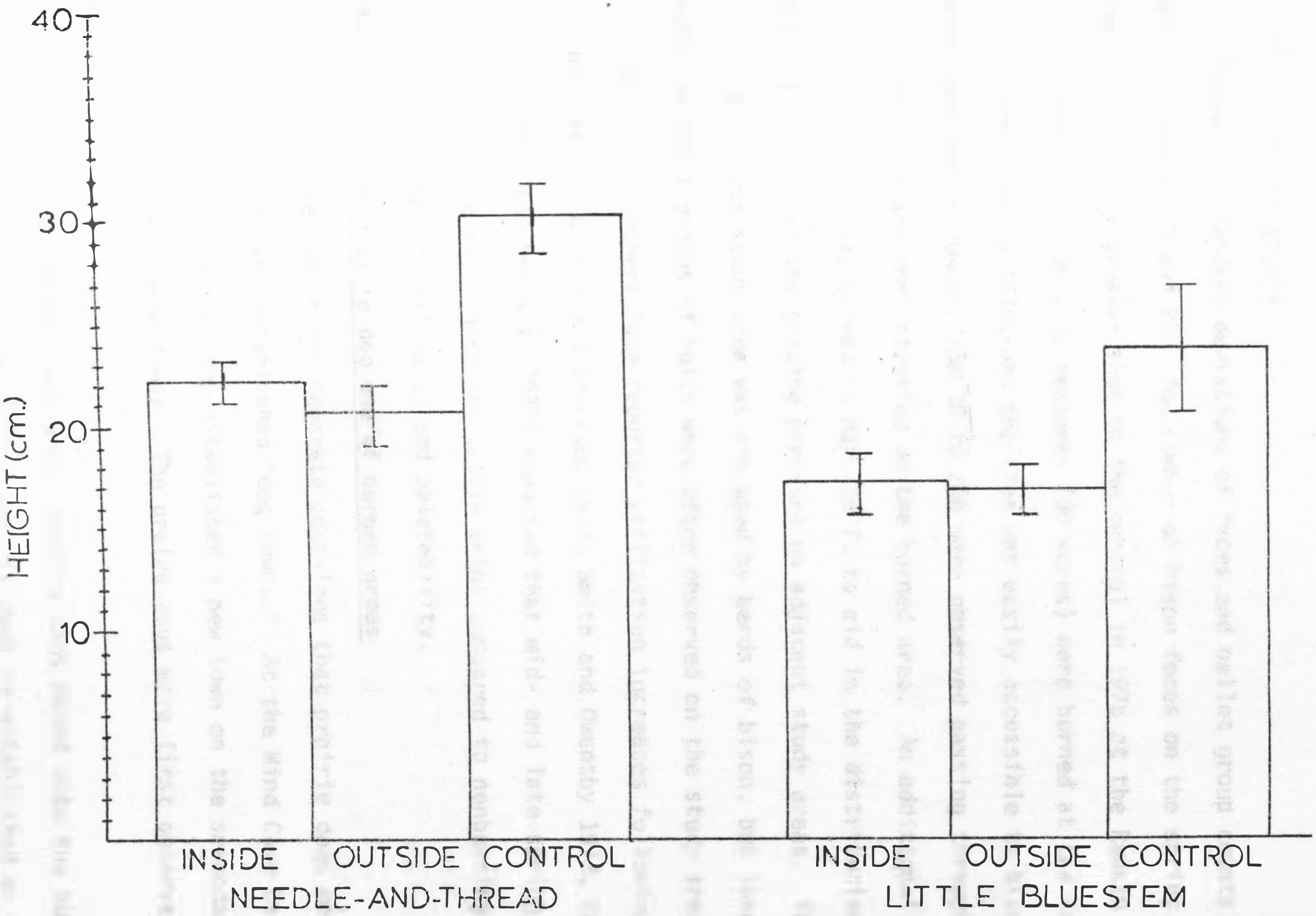


FIGURE 15. Plant Heights for 1976 Grazing Estimates at the Wind Cave Canyon Study Area. (Means are shown with 90% confidence intervals.)

Feces and pellet groups

Means and standard deviations of feces and pellet group counts are shown in Tables 19 and 20. The number of bison feces on the spring burn was significantly greater than on the control in 1976 at the Rankin Ridge study area. Only 12 hectares (30 acres) were burned at the Rankin Ridge study area in 1976, and the area was easily accessible to bison. Herds varying in number from 30 to 200 were observed passing through the study area and concentrating on the burned area. An additional area along highway 87 was burned in May, 1977, to aid in the distribution of grazing and lessen the grazing pressure on adjacent study areas. The Wind Cave Canyon study area was not used by herds of bison, but lone bulls or small groups of bulls were often observed on the study area.

Other researchers have reported utilization increases following spring burning (Barker and Erickson 1974, Smith and Owensby 1973, Vogl 1974). Smith and Owensby (1973) reported that mid- and late spring burning significantly increased cattle gains compared to nonburning due to increased nutritional value and palatability.

Observations on prairie dog use of burned areas

It was observed on two separate occasions that prairie dogs moved onto burned areas and established "dog towns." At the Wind Cave Canyon study area burn, prairie dogs established a new town on the secondary terrace above the canyon floor. The praire dogs were first observed on June 8, 1976.

At the Rankin Ridge study area, prairie dogs moved onto the buffer area that was burned in May, 1977. Prairie dogs re-established an old

Table 19

Means and Standard Deviations of Feces
and Pellet Group Counts at the
Rankin Ridge Study Area

	1976						1977					
	Elk		Bison		Deer - Antelope		Elk		Bison		Deer - Antelope	
	Mean	S. D.	Mean	S. D.	Mean	S. D.	Mean	S. D.	Mean	S. D.	Mean	S. D.
Spring Burn	5.67	1.53	25.67*	5.51	0.00	0.00	4.67	2.52	2.67	1.53	0.00	0.00
Winter Burn							6.00	1.00	3.67	2.31	0.00	0.00
Control	4.33	1.53	3.33	3.06	0.67	1.16	5.33	2.08	3.00	3.00	0.00	0.00

* Treatment is significantly different from the control at the 0.10 level of probability.

Table 20

Means and Standard Deviations of Feces and Pellet Group Counts at the Wind Cave Canyon Study Area

	1976						1977					
	Elk		Bison		Deer - Antelope		Elk		Bison		Deer - Antelope	
	Mean	S. D.	Mean	S. D.	Mean	S. D.	Mean	S. D.	Mean	S. D.	Mean	S. D.
Spring Burn	0.67	0.58	5.00	3.61	0.33	0.58	0.00	0.00	2.67	2.31	0.00	0.00
Control	1.00	0.00	2.67	1.56	0.00	0.00	0.00	0.00	2.00	1.00	0.00	0.00

town in the buffer area that was exterminated in 1952.

Prairie dogs will readily move onto areas with short vegetation cover. Elimination of tall grass cover by burning reduces the amount of mowing or grooming of an area that is required for the establishment of a prairie dog town. Thus, burned areas are readily used by prairie dogs.

CONCLUSIONS

Prescribed burning at Wind Cave National Park was effective in reducing total fuels and creating natural firebreaks suitable for controlling wildfires. In grasslands this may be effective until the mulch layer is replaced after four to five growing seasons.

Burning can reduce or eliminate dense pine thickets. Forage for wildlife can be produced in these areas where there was little or no usable forage before burning. Burning can also retard the spread of pine encroachment into grasslands. In this way, an equilibrium between pine and grassland can be maintained, re-establishing pine savannahs.

Season of burning may depend on the management objective. Winter, spring, and late spring burning were all effective in reducing Kentucky bluegrass. Winter burning increased ground cover and shortgrass yields. This may be desirable in areas of low plant density or areas with pine competition. Spring burning appeared to stimulate the production of western wheatgrass, an important component of most range sites. However, late spring burning after new growth has been initiated may reduce western wheatgrass yield and density.

Burning in late winter or spring should be conducted under proper burning conditions: air temperature of 21^{o}C (70^{o}F) or less, relative humidity of 30% or more, and steady wind speeds are under 24 kph (15 mph).

Burning when soils and mulch are moist appears to be desirable for most objectives. Total elimination of mulch exposes the soil to greater evaporation and results in a drier surface soil. Reduction in soil moisture has a direct effect on grassland yields. Prevention of total combustion of the mulch layer may aid in reducing soil moisture losses. Maintaining ground cover is recommended.

Sufficiently large acreages for research areas or additional areas near study plots should be burned in order to avoid overuse by Park ungulates, especially bison herds. Fenced study areas may be desirable for future research since bison frequently damaged exclosure cages.

Burning may be used as a management tool aiding in the distribution of ungulates. Since bison are attracted to burned areas, burning along highways may be desirable for convenient viewing by Park visitors.

Prairie dogs have become a special problem at Wind Cave National Park. Prairie dog populations are increasing rapidly and "dog towns" are increasing in size and number. Since prairie dogs readily move onto burned areas, management objectives should take this problem into consideration. Burning near existing "dog towns" should be avoided to help prevent spread of the "dog towns."

Continuing studies are necessary to determine which soil factors are affected over time by burning. Changes in soil nutrients were very small. Reducing sampling variation may be needed to detect small changes in soil nutrients that may be important to grassland yields. Repeated burning may also have a more significant effect on soil nutrients.

Additional studies of western wheatgrass response to burning may be desired. More information on the relationship between soil moisture and rhizome production after burning is needed to determine the best burning conditions to increase western wheatgrass yield and density. Response of big and little bluestem to burning was variable. Additional research is needed to determine the best burning conditions to increase big and little bluestem yields since they are desirable grasses for ungulates.

Long term studies may be desirable for determining the effectiveness of reducing pine encroachment. The effect of pine removal on watershed yields is another research possibility. Long term studies may also be desired for determining the best season for burning to accomplish a specific management objective.

BIBLIOGRAPHY

Anderson, K. L., E. R. Smith, and C. E. Owensby. 1970. Burning bluestem range. J. Range Manage. 23:81-92.

Barker, W. T., and D. O. Erickson. 1974. The effect of burning and mowing on utilization. J. An. Sci. 39:985.

Barr, Anthony J., and James H. Goodnight. 1972. A user's guide to the Statistical Analysis System. North Carolina State Univ., Raleigh, NC.

Baumberger, Rodney. 1977. South Dakota rangeland resources. Soc. Range Manage. 150 p.

Beetle, Alan A. 1970. Recommended plant names. Univ. Wyoming Agri. Exp. Sta. Bull. 31. 124 p.

Biswell, Harold H. 1967. Forest fire in perspective. Tall Timbers Fire Ecology Conf. Proc. 7:43-68.

Biswell, Harold H. 1973. Fire ecology in ponderosa pine-grassland. Tall Timbers Fire Ecology Conf. Proc. 12:69-96.

Christensen, Norman L. 1976. Short term effects of mowing and burning on soil nutrients in Big Meadows, Shenandoah National Park. J. Range Manage. 29:508-509.

Countryman, Clive M., and Donald R. Cornelius. 1957. Some effects of fire on a perennial range type. J. Range Manage. 10:39-41.

Darton, N. H. 1903. Preliminary description of the geology and water resources of the southern half of the Black Hills and adjoining regions in South Dakota and Wyoming. U.S. Geol. Surv., U.S. Gov't. Printing Off., Washington, D.C. pp. 497-599.

Daubenmire, Rexford. 1968. Ecology of fire in grasslands, 5:209-266. Advances in Ecol. Res., J. B. Cragg [ed.] Academic Press, N.Y.

Debell, D. S., and C. W. Ralston. 1970. Release of nitrogen by burning light forest fuels. Soil Sci. Soc. Amer. Proc. 34:936-938.

Debyle, Norbert V. 1976. Soil fertility as affected by broadcast burning following clearcutting in Northern Rocky Mountain larch-fir forests. Tall Timbers Fire Ecology Conf. Proc. 14:447-464.

Dodge, R. I. 1876. The Black Hills. (Reprint 1965). Ross and Haines, Inc., Minneapolis, Minn. 155 p.

Ehrenreich, John H. 1959. Effect of burning and clipping on growth of native prairie in Iowa. J. Range Manage. 12:133-137.

Gartner, F. Robert, and Wesley W. Thompson. 1973. Fire in the Black Hills forest-grass ecotone. Tall Timbers Fire Ecology Conf. Proc. 12:37-68.

Gary, Howard L. 1975. Watershed management problems and opportunities for the Colorado Front Range ponderosa pine zone: The status of our knowledge. U.S. Dep. Agr. Forest Serv., Res. Pap. RM-139. 32 p.

Harvey, Walter R. 1972. Instructions for use of Least Squares Method Program. Ohio State Univ., Columbus, Ohio. n.p.

Holden, M. W. 1975. The importance of fire in maintaining native prairie vegetation in North Central United States. South Dakota State Univ. (unpublished).

Jackson, M. L. 1958. Soil chemical analysis. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

Johnson, H. N. 1949. A climatological review of the Black Hills. South Dakota School of Mines and Technol., Black Hills Eng. 29(1):3-15.

Jordan, C. F. 1965. Fire influences in old fields of the New Jersey Piedmont. New Jersey Acad. Sci. Bull. 10:7-12.

Kayll, A. J. 1974. Use of fire in land management, p. 483 to 511. In T. T. Kozlowski and C. E. Ahlgren [ed.] Fire and ecosystems. Academic Press, N.Y.

Knight, H. 1966. Loss of nitrogen from the forest floor by burning. For. Chronicle 42(2):149-152.

Komarek, E. V., Sr. 1976. Fire ecology review. Tall Timbers Fire Ecology Conf. Proc. 14:201-216.

Launchbaugh, J. L. 1973. Effect of fire on shortgrass and mixed prairie species. Tall Timbers Fire Ecology Conf. Proc. 12:129-151.

Lewis, C. E., and T. J. Harshbarger. 1976. Shrub and herbaceous vegetation after 20 years of prescribed burning in the South Carolina Coastal Plains. J. Range Manage. 29:13-18.

Lindenmuth, A. W. 1962. Effects on fuels and trees of a large intentional burn in ponderosa pine. J. For. 60:804-810.

Lovaas, A. L. 1976. Introduction of prescribed burning to Wind Cave National Park. Wildl. Soc. Bull. 4(2):69-73.

Marshall, R., and C. Averill. 1928. Soil alkalinity on recent burns. Ecology 9:533.

Mayland, H. F. 1967. Nitrogen availability on fall-burned oak-mountainmahogany chaparral. J. Range Manage. 20:33-35.

McIntosh, Aurthur C. 1927. Some sources of the Black Hills flora. South Dakota School of Mines and Technol., Black Hills Eng. 15:38-44.

McIntosh, Aurthur C. 1949. A botanical survey of the Black Hills of South Dakota. South Dakota School of Mines and Technol., Black Hills Eng. 28:3-74.

McMurphy, W. E., and K. L. Anderson. 1965. Burning Flint Hills range. J. Range Manage. 18:265-269.

Newton, H. and W. P. Jenny. 1880. Report of the geology and resources of the Black Hills of Dakota. Geogr. and Geol. Survey, Rocky Mtn. Region. U.S. Gov't Printing Off., Washington, D.C. 566 p.

Odum, Eugene P. 1971. Fundamentals of ecology. W. B. Saunders Co., Philadelphia. 574 p.

Olsen, S. R., and L. A. Dean. 1965. Phosphorus. p. 1035-1049. In C. A. Black [ed.] Methods of soil analysis, Agronomy 9. Amer. Soc. Agron., Madison, Wisc.

Orr, Howard K. 1959. Precipitation and streamflow in the Black Hills. U.S. Dep. Agr. Forest Serv., Rocky Mtn. Forest and Range Exp. Sta., Sta. Paper No. 44. 25 p.

Orr, Howard K., and Tony Vanderheide. 1973. Water yield characteristics of three small watersheds in the Black Hills of South Dakota. U.S. Dep. Agr. Forest Serv., Res. Pap. RM-100, 8 p.

Owensby, C. E., and J. B. Wyrill, III. 1973. Effects of range burning on Kansas Flint Hills soil. J. Range Manage. 26:185-188.

Packer, Paul E., and Bryan D. Williams. 1976. Logging and prescribed burning effects on the hydrologic and soil stability behavior of larch/Douglas-fir forests in the Northern Rocky Mountains. Tall Timbers Fire Ecology Conf. Proc. 14:465-479.

Roach, D. 1974. Prescribed burning in the Black Hills. South Dakota Conserv. Dig. 41(5):40-43.

Sauer, C. O. 1950. Grassland climax, fire, and man. J. Range Manage. 3:16-21.

Shilts, Deane M. 1976. Experimental burning in Wind Cave National Park. Presented at the Prescribed Fire and Ponderosa Pine Management Program, Chadron State College, Chadron Nebr. Feb. 18, 1976. 6 p.

Smith, E. F., and C. E. Owensby. 1973. Effects of fire on True Prairie grasslands. Tall Timbers Fire Ecology Conf. Proc. 12:9-22.

Steele, Robert G. D., and James H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc., N.Y. 481 p.

Stoddart, L. A., A. D. Smith, and T. W. Box. 1975. Range management, 3rd ed. McGraw-Hill Book Co., Inc., N.Y. 532 p.

Storms, W. H. 1906. The early history of the Black Hills, South Dakota. Mining World. 19 p.

Strickler, G. S., and F. W. Stearns. 1962. The determination of plant density. Range Res. Methods. U.S. Dep. Agr. Misc. Pub. 940. 172 p.

Thelinius, J. F. 1970. An isolated occurrence of limber pine (*Pinus flexilis* James) in the Black Hills of South Dakota. Amer. Midl. Naturalist 84(2):411-417.

U. S. Dep. of Agriculture. 1969. Conservation plan for Wind Cave National Park. Lincoln, Nebr. 46 p.

U. S. Dep. of the Interior. 1967. Natural resources of South Dakota. U. S. Gov't Printing Off., Washington, D.C. 72 p.

U. S. Dep. of the Interior. 1973. Approved negative declaration for experimental prescribed burning in Wind Cave National Park. Omaha, Nebr. 11 p.

Vallentine, John F. 1971. Range development and improvements. Brigham Young Univ. Press, Provo, Utah. 516 p.

Viro, P. J. 1974. Effects of forest fire on soil, p. 7-45. In T. T. Kozlowski and C. E. Ahlgren [ed.] fire and ecosystems. Academic Press, N.Y.

Vlamis, J., H. H. Biswell, and A. M. Schultz. 1955. Effects of prescribed burning on soil fertility in second growth ponderosa pine. J. For. 11:905-909.

Vlamis, J., and K. D. Gowans. 1961. Availability of nitrogen, phosphorus, and sulfur after brush burning. J. Range Manage. 14:38-40.

Vogl, Richard J. 1974. Effects of fire on grasslands, p. 139-194. In T. T. Kozlowski and C. E. Ahlgren [ed.] Fire and ecosystems. Academic Press, N.Y.

Weaver, Harold. 1967. Fire and its relationship to ponderosa pine. Tall Timbers Fire Ecology Conf. Proc. 7:127-149.

Weaver, Harold. 1974. Effects of fire on temperate forests: Western United States, p. 279-319. In T. T. Kozlowski and C. E. Ahlgren [ed.] Fire and ecosystems. Academic Press, N.Y.

White, E. M., and F. R. Gartner. 1975. Immediate effects of prairie fire on the soil nitrate, ammonium, available phosphorus and total N contents. Proc. South Dakota Acad. Sci. 54:188-193.

APPENDIX A

Scientific and common names of all grasses and grasslike plants, forbs, and shrubs encountered in and near the study areas at Wind Cave National Park. Nomenclature follows that of A. Beetle's booklet, Recommended Plant Names (1970), except where indicated by an asterisk.

APPENDIX A

Scientific Name	Common Name
Grasses and Grasslike Plants:	
Agropyron smithii	Western wheatgrass
Agropyron spicatum	Bluebunch wheatgrass
Andropogon gerardii	Big bluestem
Andropogon scoparius	Little bluestem
Aristida longiseta	Red threeawn
Bouteloua curtipendula	Sideoats grama
Bouteloua gracilis	Blue grama
Bromus inermis	Smooth brome
Bromus japonicus	Japanese brome
Buchloe dactyloides	Buffalograss
Calamovilfa longifolia	Prairie sandreed
Carex eleocharis	Needleleaf sedge
Carex filifolia	Threadleaf sedge
Eragrostis spectabilis	Purple lovegrass
* Festuca octoflora	Six weeks fescue
Hordeum jubatum	Foxtail barley
Koeleria cristata	Prairie junegrass
Muhlenbergia cuspidata	Stoneyhills muhly
Oryzopsis micrantha	Littleseed ricegrass
Poa compressa	Canada bluegrass
Poa pratensis	Kentucky bluegrass
Poa secunda	Sandberg's bluegrass
Sitanion hystrix	Bottlebrush squirreltail

Scientific Name	Common Name
Stipa comata	Needleandthread
Stipa viridula	Green needlegrass
Forbs:	
Achillea millefolium	Common yarrow
Agoseris glauca	Pale agoseris
Allium cernuum	Nodding onion
Allium textile	Prairie onion
Ambrosia spp.	Ragweed
Amorpha canescens	Leadplant amorpha
Amorpha nana	Dwarfindigo amorpha
Androsace occidentalis	Western rockjasmine
Anemone patens	Spreading pasqueflower
Antennaria neglecta	Field pussytoes
Arabis hirsuta	Hairy rockcress
Argemone intermedia	Bluestem pricklypoppy
Artemisia frigida	Fringed sagewort
*Artemisia ludoviciana	Cudweed sagewort
Asclepias pumila	Plains milkweed
Aster laevis	Smooth aster
Aster oblongifolius	Aromatic aster
Astragalus alpinus	Alpine milkvetch
Astragalus crassicarpus	Groundplum milkvetch
Astragalus missouriensis	Missouri milkvetch
Astragalus spatulatus	Spoonleaf milkvetch

Scientific Name	Common Name
Calochortus gunnisoni	Gunnison mariposalily
Calochortus nuttalli	Sego mariposalily
Campanula rotundifolia	Bluebell bellflower
Castilleja sessiliflora	Largeflower Indianpaintbrush
Cerastium arvense	Field cerstium
Chrysopsis villosa	Hairy goldenaster
Cirsium spp.	Thistle
Cleome serrulata	Rockymountain beeplant
Collomia linearis	Narrowleaf collomia
*Cryptantha celosioides	Miner's candle
*Cynoglossum officinale	Common houndstongue
Delphinium bicolor	Little larkspur
Descurainia sophia	Flixweed tansymustard
Dodecatheon pauciflorum	Darkthroat shootingstar
*Echinacea pallida	Blacksampson
Erigeron lonchophyllus	Spearleaf fleabane
Erysimum asperum	Plains wallflower
Galium boreale	Northern bedstraw
Gaura coccinea	Scarlet gaura
*Geum triflorum	Prairiesmoke
Glycyrrhiza lepidota	American licorice
Grindelia squarrosa	Curlycup gumweed
Haplopappus spp.	Goldenweed
Helianthus spp.	Sunflower

Scientific Name	Common Name
Hymenoxys acaulis	Stemless actinea
* Lactuca spp.	Wild lettuce
Lathyrus polymorphus	Peavine
*Lesquerella alpina	Alpine bladderpod
Leucocrinum montanum	Common starlily
Liatris punctata	Dotted gayfeather
Lilium philadelphicum	Wood lily
Linum perenne	Perennial flax
Lithospermum incisum	Narrowleaf gromwell
Lithospermum ruderale	Western gromwell
Lomatium foeniculum	Hairyseed lomatium
Lygodesmia juncea	Rush skeletonplant
*Mammillaria spp.	Pinchusion cactus
Melilotus spp.	Sweetclover
Mentzelia decapetala	Tenpetal mentzelia
Mertensia lanceolata	Lanceleaf bluebells
* Monarda fistulosa	Horsemint
* Musineon tenufolium	Wild parsley
* Oenthera serrulata	Eveningprimrose
Opuntia polyacantha	Plains pricklypear
Oxytropis sericea	Silky loco
Penstemon albidus	White penstemon
Penstemon gracilis	Slender penstemon
Penstemon grandiflorus	Shellleaf penstemon

Scientific Name	Common Name
Petalostemon purpureum	Purple prairieclover
*Phlox alyssifolia	Phlox
Phlox andicola	Plains phlox
Phlox hoodii	Hoods phlox
Physalis spp.	Groundcherry
*Plantago purshii	Wooly Indianwheat
*Plantago spinulosa	Spiny Indianwheat
Polygala alba	White polygala
Potentilla gracilis	Northwest cinquefoil
Potentilla hippiana	Horse cinquefoil
Psoralea argophylla	Silverleaf scurfpea
Psoralea esculenta	Common breadroot scurfpea
Psoralea tenuiflora	Slimflower scurfpea
*Ranunculus rhomboides	Buttercup
Ratibida columnifera	Upright prairieconeflower
Senecio crassulus	Thickleaf groundsel
Sisyrinchium montanum	Colorado blueeyedgrass
*Solanum rostratum	Buffalobur
Solidago nemoralis	Dyersweed goldenrod
Solidago rigida	Stiff goldenrod
Sphaeralcea coccinea	Scarlet globemallow
*Taraxacum officinale	Dandelion
Thermopsis rhombifolia	Prairie thermopsis
Thlaspi arvense	Field pennycress
Tradescantia bracteata	Bracted spiderwort

Scientific Name	Common Name
Tragopogon dubius	Yellow salsify
Verbena stricta	Woolly verbena
Viola nuttallii	Yellow prairie violet
Viola pedatifolia	Purple prairie violet
Zigadenus venenosus	Meadow deathcamus
Mosses:	
Selaginella densa	Spikemoss selaginella
Shrubs:	
Amelanchier alnifolia	Saskatoon seviceberry
Cercocarpus montanus	True mountainmahogany
Physocarpus opulifolius	Common ninebark
Prunus americana	American plum
*Prunus virginiana	Chokecherry
*Rhus radicans	Poison ivy
Rhus trilobata	Skunkbush sumac
Ribes cereum	Wax current
Ribes odoratum	Clove current
*Ribes setosum	Spiny current
Rosa arkansana	Arkansas rose
Symphoricarpos occidentalis	Western snowberry

APPENDIX B

Monthly Precipitation Totals for the Wind Cave National Park Area. (Reported in Inches)

	1976			1977		
	Custer[a]	Hot Springs[b]	Wind Cave	Custer	Hot Springs	Wind Cave
Jan.	0.46	0.60	0.50	0.47	0.41	
Feb.	1.81	0.70	0.50	0.30	0.06	
March	0.64	0.68	0.90	1.58	0.99	
April	3.50	3.37	4.00	1.58	2.44	
May	3.29	1.82	2.80	1.43	2.40	1.87
June	5.01	3.68	4.10	2.76	2.13	1.37
July	2.68	4.01	3.20	5.10	3.72	2.05
Aug.	2.24	1.22	1.70	3.96	2.93	3.08
Sept.	0.82	0.64	0.70			3.24
Oct.	0.24	0.36	0.40			
Nov.	0.42	0.18	0.20			
Dec.	0.26	0.13	0.10			
Annual Total	21.37	17.42	19.10			

[a] Custer is located approximately 11 miles NW of Wind Cave National Park.

[b] Hot Springs is located approximately 7 miles south of Wind Cave National Park.